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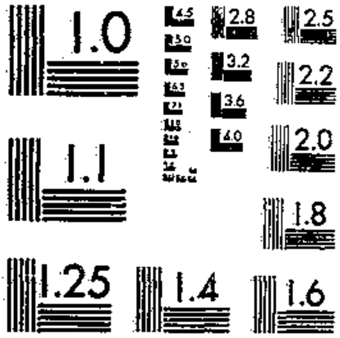

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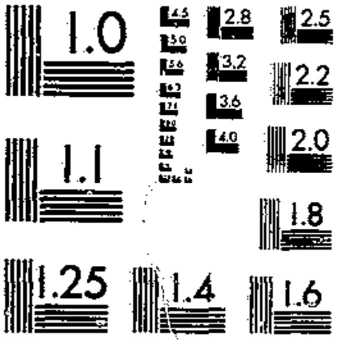

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TECHNICAL BULLETIN No. 502 DECEMBER, 1935

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THE CHEMICAL AND PHYSICAL PROPERTIES OF DRY-LAND SOILS AND OF THEIR COLLOIDS

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INTRODUCTION

The system of soil classification developed by the Division of Soil Survey has been based largely on the field examination of soils and is comprehensively presented by Marbut (*29*).[1] As a cumulative result of these studies and of similar previous and contemporaneous studies elsewhere (*42*) it is possible to state that soil morphology is a resultant of a number of causal influences. Among those especially important are rainfall, temperature, vegetative cover, parent material, drainage, and erosion. It must, of course, also be recognized that the time during which these forces have operated determines to a large degree the extent to which a soil has reached full development. The many studies of the chemical and physical properties of the soil made in the United States and elsewhere have brought out very definitely that the soil component of primal importance in determining its character is its colloid. Through these studies it has appeared that a given soil series is characterized by a colloid in which there is striking uniformity of composition (*21*, *23*, *24*, *32*), particularly with respect to the major components. As for different soil series colloidal distinctions are to be expected. It also appears that the great soil groups are characterized by the presence of colloids which sharply differentiate the groups when selected representatives are chosen (*3*, *12*).

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[1] Italic numbers in parentheses refer to Literature Cited, p. 54.

Since the studies of Cushman (*17*) and Cushman and Hubbard (*18*) it has become increasingly apparent that the hydrolysis of minerals is the dominant chemical process in the production of the colloid, while its final character is influenced by various chemical and physical processes. In various publications the importance of different influences has been stressed. For example, in the work of Robinson and Holmes (*41*) and of Reifenberg (*36*) the importance of rainfall was emphasized, while Crowther (*16*) and Jenny (*25*) have stressed the influence of temperature. Brown, Rice, and Byers (*7*) examined a series of soils from Nebraska which under a fairly wide rainfall showed small differences of colloid character, though there were wide differences in the distribution of the colloid within the profile. In these soils the mean annual temperature is nearly the same, the parent material presumably the same, and the vegetative cover likewise very similar. All of the soils in question belong to the Pedocal division.

It therefore seemed very worth while to examine carefully a series of soils in which the distinctive environmental condition is a difference of temperature. In selecting the soils for examination advantage was taken of specially favorable opportunity for processing certain profiles. In order to secure the temperature range desired soils of diverse parent material had to be selected. All fall in the division of Pedocal soils. While the chief purpose of the study is an examination of the soil colloids, the data obtained include both the mechanical and chemical analyses of the whole soil.

The collection and description of the profiles examined could only have been possible as a result of whole-hearted cooperation by the members of the Soil Survey Division.

DESCRIPTION OF THE SOILS

The soils presented here are not all of agricultural importance, but were selected to show the specific effect of climate, parent material, and other factors which have combined to produce the soil as it now is. Information and data have been liberally taken from other publications, as cited. The following descriptions are divided into three parts: (1) A general description, if available, of each soil series furnished by the Division of Soil Survey of this Bureau; (2) a general description of the specific soil obtained in part from the collector; and (3) the specific description of the profile by the collector.

Following the more recent practice of the Division of Soil Survey, the portions of the vertical section of the soils have only been numbered. They will be referred to as horizons as a matter of convenience, although morphological differences are not readily distinguished in dry-land soils.

SCOBEY SERIES

The soils of the Scobey series are normally developed over an extensive area which begins in the western part of North Dakota, extends in a northwesterly direction across the northern plains of Montana, and continues to an unknown distance into Canada. The greater part of the area lies between elevations of 2,000 and 3,000 feet above sea level. A gradation in the color of the surface soil takes place across this belt, the darkness of color decreasing westward in proportion to the lower precipitation and the resulting thinner grass cover. The average and characteristic color of the surface soil is dark grayish brown and, in the European classification, these soils would probably be grouped with the Chestnut-Brown soils. The parent material is a calcareous drift deposited during the Wisconsin glaciation. The surface features are those of a nearly level to gently rolling drift plain. Drainage is everywhere well established. The native vegetation consists of the mixed prairie grasses of which grama, needlegrass, buffalo grass, western wheatgrass, and junegrass are most common. The mean annual precipitation over the region occupied by the Scobey soils ranges from 13 to 15 inches. The sample described below was taken in the extreme eastern part of the belt of Scobey soils, and the surface layers are therefore darker and the solum thicker than in the average development of this series.

Mapped in Milk River Area, Mont., 1928.

SCOBEY LOAM

The normal soil for the western part of North Dakota is the Scobey loam. It is a typical dark-brown soil developed on the rolling, well-drained surface over wide areas. Internal and external drainage are good and roots penetrate the whole soil mass with ease. The profile sampled has never been plowed.

Collector—M. J. Edwards and K. Ableiter.

Location—Southwest corner of sec. 7, T. 151 N., R. 100 W., McKenzie County, N. Dak.

Climate—Mean annual rainfall, 13.67 inches; mean annual temperature, 39.8° F.

1. 0 to 1½ inches, dark grayish-brown light loam; fine soft crumb structure. Has much very fine sand. Many grass roots. Sample includes surface sod.
2. 1½ to 5 inches, dark-brown loam (very slightly reddish), soft crumb structure. In situ the soil is faintly platy, grading in the lower part into the upper part of the prisms of horizon 3. This part of the soil has many grass roots. Very few pebbles.
3. 5 to 13 inches, brown, with reddish tinge (or chestnut-brown) sandy clay loam. Prisms somewhat larger and more massive in the very upper part. Very well developed prismatic structure; prisms mostly ½ to 1½ inches in diameter. When removed the soil is in elongated pieces ranging from small to large nut, and held together by the grass roots. The mass is fairly easily crushed to medium hard crumb. Quite brittle when dry. Vesicular. Very few pebbles.
4. 13 to 20 inches, brown, with light olive-drab tinge (or grayish-brown), sandy clay loam. Well-developed prismatic structure, but the prisms and their constituent blocks are larger than in horizon 3. A few pebbles. Just a little less friable than horizon 3. Effervesces mildly (very mildly in upper part). A little less vesicular than horizon 3.
5. 20 to 24 inches, light olive-drab, strongly mottled with white, sandy clay till. Compact in places but easily friable. The prismatic structure of the solum fades in the upper part of horizon 5. Sample of horizon 5 largely from the region of carbonate accumulation.

SPEARFISH SERIES

The soils of the Spearfish series are chocolate brown to red and sometimes carry sufficient organic matter to impart a dark-brown color to the immediate surface. The subsoils are reddish brown to red. Fragments of gypsum occur in both surface soil and subsoil. The subsoils are underlain by a stratum of gypsum or gypsum-bearing rocks, often at shallow depths. The series is developed in place and is derived from gypsum-bearing shales and sandstones. The topography is level to gently rolling. The series is of extensive distribution but has not been extensively mapped. Occurring ordinarily in regions of low rainfall, it is not of great agricultural importance. The formations giving rise to this series are readily eroded, consequently the present surface soil has not remained in place sufficiently long to develop a profile. The soils are therefore very immature.

Mapped in South Dakota, 1907.

Revised by T. D. Rice, June 1917.

SPEARFISH SILT LOAM

An extensive and representative development of this soil occurs in South Dakota and Wyoming in a comparatively narrow belt surrounding the Black Hills in South Dakota and Wyoming. The uplift of the Black Hills tilted and exposed previously nearly horizontal beds. Among these is comparatively soft Spearfish formation, probably of Triassic age, consisting of red sandy shales interspersed with gypsum. Along the eastern side of the Black Hills the exposure is 1 or more miles wide, but is normally 4 to 5 miles wide along the southwestern slope. This easily decomposed formation was rapidly removed and an annular valley was formed around the main dome of the hills and flanked on the outer side by a rampart of hills having a steep inner slope. The vegetation is chiefly buffalo grass; blazing-star and wild aster are common on the steeper slopes.

Collector—H. G. Byers. Described by F. A. Hayes.

Location—Three-fourths mile north of Piedmont, Mead County, S. Dak., in the northeast corner of sec. 9, T. 3 N., R. 6 E.

Climate—Mean annual rainfall, 17.71 inches; mean annual temperature, 46.2° F.

1. 0 to 12 inches, pale reddish brown. Very friable, structureless, but coherent, not compact. Contains scattering siliceous pebbles. The upper 10 inches slightly darker than the remainder. This layer contains the organic material of the profile.
2. 12 to 24 inches. Same as above except red and slightly granular, also a trifle more compact. This is evidently the B horizon but is very poorly developed.
3. 28 to 42 inches, red, very friable; this is apparently the disintegrated material of the Spearfish formation. Numerous less-weathered Spearfish fragments are present but seldom exceed 1 inch in dimensions.
4. 60 to 72 inches. The finer material similar to horizon 3 contains fragments of gypsum. This gypsum is a fragmented deposit in the Spearfish shale. Three-fourths mile to the east the gypsum is being mined. It occurs there in a band about 4 feet thick.

BADLANDS[1]

The Badlands consist mainly of the severely eroded parts of the Brule, Chadron, and Pierre formations. They are developed most frequently from the Brule material, a pinkish sandy clay. Erosion is so rapid and the subsoil material so unfavorable to immediate plant growth that the areas are quite devoid of vegetation. The resulting topography is unique, in some instances very roughly dissected, and again quite flat. The Badlands were mapped in Sioux County, Nebr., in 1919.

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[1] Not classified as a soil by the U. S. Soil Survey, therefore no series designation is used.

BADLANDS SILT LOAM

The Badlands of South Dakota are typically developed in the area just southeast of the Black Hills between the White and Cheyenne Rivers. They are the highly dissected remains of a vast outwash plain sloping eastward from the Rocky Mountains. According to Darton and Paige (*19*) the Brule clay on which this soil is developed consists of sandy clays, fuller's earth, volcanic ash, and sandstone. Also, one of the principal materials is a peculiar clay of a pale flesh color to light brownish buff, porous and crumbling when dry but massive, compact, and light brown when damp. It resembles fuller's earth and differs from ordinary clay in being less plastic.

This immature soil differs little from the parent formation owing to the low rainfall and sparse short-grass cover. The samples were collected from the flat top of a small butte and consist for the most part of undifferentiated compact sandy material.

Collector—H. G. Byers.

Location—1 mile northeast of Interior, Jackson County, S. Dak.

Climate—Mean annual rainfall, 14.54 inches; mean annual temperature, 46.0° F.

1. 0 to 1 inch. Dust mulch.
2. 1 to 12 inches. Undifferentiated grayish-white compact sandy clay.
3. 12 to 30 inches. Same as layer above.
4. 72 to 84 inches. Parent material.

PIERRE SERIES

The Pierre soils are extensively developed by the soil-forming process from fine-grained shales. In the central part of South Dakota the parent material of these soils is the Pierre shale formation of the Cretaceous system. This is a region where the normally developed surface soil is nearly black, but over eroded areas two factors have combined to prevent the formation of the normal soil: The rapid run-off of rainfall from the slopes has resulted in a drier soil climate than corresponds to the rainfall, and erosion has removed the black soil almost as rapidly as it has formed. For these reasons the lighter colored soils of this region are correlated with the Pierre series which is the normal soil of the more arid region farther west.

The surface soils of the Pierre series have a thickness of 8 to 12 inches and are slate colored, olive brown, or olive gray. These soils are heavy in texture except on comparatively small areas where the surface layer has been modified by wind-laid sands. The surface layer of Pierre clay when moderately moist is finely granular and mellow but when wet it runs together into a very sticky mass. It is underlain, as are all types of this series, by an olive-brown or olive-gray clay. The granular structure usually continues through this layer. Below a depth of 18 or 20 inches there is often a heavy clay or claypan with prismatic structure. It is similar in color to the layers above, but the texture is slightly heavier. The material at a usual depth of 36 to 40 inches becomes more friable. The parent material, an olive-gray shale, is usually encountered at a depth of 4 to 6 feet. The surface is characterized by rounded hills and ridges. Surface drainage is good.

Established in Belle Fourche area, S. Dak., 1907. Revised by T. D. Rice, June 1917.

PIERRE CLAY

The Pierre clay consists of dark-brown to yellow-brown surface soil underlain by a heavy subsoil. In this area it is derived from the Pierre shale somewhat influenced by later deposits. The usual texture is that of a loam, fairly silty, or a heavy silt loam which often possesses some of the sticky nature of gumbo. A fair amount of organic matter gives the soil a brown to grayish-brown color. At a depth of 6 to 12 inches lighter colored, heavier, and more compact material tends to break up in cubes as do the western adobes. At a depth of 3 to 6 feet the soil grades into gray or slate-colored shale. The samples were collected from a gentle slope.

Collector—T. D. Rice and H. G. Byers, September 24, 1933.

Location—50 feet from the north end of plot 582, sec. 21, T. 100 N., R. 72 W., Gregory County, S. Dak.

Climate—Mean annual rainfall, 14.54 inches; mean annual temperature, 47.2° F.

1. 0 to 8 inches, dark olive-gray heavy clay, granular and calcareous. Includes 2 inches of mulch, more finely granular than rest of sample. The mulch, though loose and friable when dry, becomes very sticky when wet.
2. 8 to 18 inches, olive-gray clay, very granular layer. Slightly heavier in texture than horizon 1. Calcareous.
3. 18 to 40 inches, olive-gray clay. Very compact and prismatic structure, readily fractured columns. Slightly heavier in texture than horizons 1 and 2. Calcareous.
4. 40 to 60 inches, light olive-gray clay, no gypsum. Very calcareous. Structureless.
5. 60 to 74 inches, light olive-gray clay. Structureless. Very calcareous. No gypsum crystals.

KEITH SERIES

The surface soil of the Keith series to an average depth of about 12 inches consists of a grayish-brown or dark grayish-brown loose fine-granular material. A slight change to a grayish-brown color and a heavier texture takes place with depth, and the structure becomes somewhat compact. This at about 30 inches is abruptly underlain by a grayish-white or light grayish-yellow friable material. The carbonates have been largely leached out of the upper two horizons, but the lowest has a high concentration of calcium and other carbonates. The soil is underlain, at a depth of 36 to 48 inches, by parent material, the floury silt of Peorian loess.

Established in Deuel County, Nebr., 1921.

KEITH SILT LOAM

The Keith series is developed under an average annual rainfall of less than 20 inches. The soils are definitely in the short-grass prairie region. A low organic content has resulted in a dark grayish-brown or chestnut-brown surface layer. The soils have a barely perceptible compaction in the upper part of their subsoils. The surface drainage and underdrainage are excellent. There is little or no erosion. They occupy loess-covered very gentle slopes or flat uplands. The native grasses are western wheatgrass and grama.

Collector—F. A. Hayes.

Location—1,628 feet north of the southwest corner of sec. 34, T. 14 N., R. 36 W., Dundy County, Nebr.

Climate—Mean annual rainfall, 16.85 inches; mean annual temperature, 49.9° F.

1. 0 to ½ inch, grayish-brown structureless silt loam.
2. ½ to 3½ inches, chestnut-brown laminated silt loam.
3. 3½ to 14 inches, dark grayish-brown friable structureless or mealy silt loam. Worm and insect borings and casts rather numerous. Material breaks into soft clods of irregular sizes and shapes.
4. 14 to 21 inches, upper part of lime zone. Grayish-brown cloddy friable silt loam. Limy. Carbonates occur in small soft spots, in splotches, and as filmlike coatings on the surfaces of clods. Borings very abundant.
5. 21 to 33 inches, the zone of maximum lime accumulation. Light grayish-brown structureless silt loam. Lime very abundant, occurring both in disseminated form and as coatings on clods. Material breaks into irregular-shaped clods which are moderately hard to crush between fingers and thumb.
6. 33 to 40 inches, very light grayish-brown structureless silt. Very limy. Material breaks into rather definite clods of various sizes and shapes, but they are softer than in layer above.
7. 40 to 48 inches, same as layer above, except it has a floury consistency. In this horizon very little of the lime is visible, most of it being in disseminated form.
8. 48 to 72 inches, the parent loess. Light grayish-brown floury silt. Limy.
9. 72 to 96 inches, same as layer above.

HAYS SERIES

In the reconnaissance survey of western Kansas (*14*) the Hays soils were designated as members of the Summit series. Since that time it has been necessary to define the Summit series more accurately, and as a result the Summit soils are now confined to the humid portion of eastern Kansas and the dark-colored soils farther west, derived from similar parent materials (Tertiary shale) and occupying similar positions, are designated as Hays soils in Dr. Marbut's recent revision of the western Kansas reconnaissance.

The surface soil of the Hays series consists of a brown to dark-brown structureless layer about 4 inches thick. This is underlain by a very dark brown to nearly black, highly granular layer which reaches a depth of 16 inches. Beneath the second layer the material is heavy, rather tough, and tends to break vertically into irregular prisms, and these in turn break into angular particles. The angular particles are dark brown due to a coating of organic matter, but the interiors are lighter in color. The zone of carbonate accumulation begins at a depth of about 30 inches and is about 2 feet in thickness. It is definitely developed but is not highly concentrated. Below this is the parent material consisting of more or less completely decomposed shale, sandstone, or limestone, from which the Hays soils are developed. Where the material has weathered from very fine grained shales, it develops into heavy soils, in most places, clay loams.

These soils are best developed on the smooth upland plains. The heavy layer thins, softens and, in places, disappears on rolling to hilly areas.

Because of the smoothness of the plain, the relatively high rainfall, and the highly productive character of the soil, the area occupied by these soils, is a great wheat-growing region. Over a large part of the area of these soils in Kansas, about 80 percent of the acreage of cultivated land, is in wheat.

Series established by C. F. Marbut, 1934.

Description furnished by T. D. Rice.

HAYS SILTY CLAY LOAM

The surface soil of Hays silty clay loam is dark gray or dark brownish gray. Just beneath this layer the subsoil is similar or slightly lighter in color, of heavier texture, of compact structure, and ranges from 2 to 8 inches in thickness. Beneath this layer the subsoil is a light-brown or yellowish-brown silt loam of mealy consistency and friable character. These soils are developed on level to sharply rolling land. Both surface and under drainage are excellent.

The samples of Hays silty clay loam were collected by R. H. Davis from the Kansas Agricultural Experiment Station and are described as follows:

Location—1 mile south of Hays, Kans.

Climate—Mean annual rainfall, 22.8 inches; mean annual temperature, 54.3° F.

1. 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 splotched 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 2 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. 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. 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. 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. 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. 60 to 72 inches, buff-colored material which is of silghtly coarser texture than the layer above, of 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.

PULLMAN SERIES

The surface layer of the Pullman soils is brown or grayish brown and becomes quite dark when wet. It contains no free calcium carbonate and is moderately supplied with organic matter. The average thickness of this layer is about 5 inches. The upper part of the subsoil, which reaches an average depth of about 24 inches, is dark chocolate-brown clay, very hard when dry and plastic when wet. When moist this material breaks down to a fine-granular condition, but when dry it breaks into roughly cubical blocks. The surfaces of these blocks are slick or varnishlikē. The next lower layer is a calcareous clay with a few soft lime concretions. The color is chocolate brown or dark reddish brown, the red color increasing with depth. The upper part of this layer is as compact as the layer above, but the lower part becomes gradually more friable. Below a usual depth of 48 inches the material is a red or brownish-red calcareous clay containing a large number of soft lime concretions. A layer of carbonate concentration begins at a depth of about 5 feet and has a thickness of about 2 feet. Usually more than half of the volume consists of aggregations of soft white lime carbonate and the rest of the material is light-brown calcareous clay. Below this is the parent material, a light-brown or buff highly calcareous clay and small soft lime concretions which make up about 15 percent of the volume of the material.

Mapped in Potter and Randall Counties, Tex., 1929.

PULLMAN SILTY CLAY LOAM

Pullman silty clay loam, formerly known as Amarillo silty clay loam, is known locally as "High Plains tight land" and occupies a large proportion of the total area of the High Plains in the Texas Panhandle both north and south of the Canadian River. The surface relief is flat to gently sloping. Run-off water collects in intermittent lakes, 2 to 50 feet below the general level. Hence there is no regional drainage although the internal drainage is good. The soil-forming material is a friable highly calcareous reddish-buff clay containing a considerable amount of soft white or cream-colored concretions, and is a part of the outwash plain material deposited by rivers flowing eastward from the Rocky Mountains during the Cenozoic period.

Collector—E. H. Templin.

Location—1 mile northeast of Masterson, Nash County, Tex., in a cut along the Chicago, Rock Island & Gulf Railway.

Climate—Mean annual rainfall, 20.8 inches; mean annual temperature, 55.8° F.

1. 0 to 5 inches, silty clay loam which is very dark brown when moist and dark grayish brown when dry. The material has a slight horizontal arrangement but no well-defined platiness or lamination. It is slightly hard when dry, friable when moist, and slightly plastic when wet.
2. 5 to 24 inches, clay which is dark chocolate brown when wet and chocolate brown when dry. Following frosts or while moist following rains, the exposed surfaces of this layer assume a very fine granular condition. However, the unexposed material, regardless of moisture condition, shows little granulation. When dry the material in this layer contracts into irregular very hard blocks, 2 or 3 inches in diameter, with uneven faces and a roughly cubical shape. The surfaces of these blocks are slick, or varnishlike, and they have characteristic bumpy or granular surfaces, indicating a slight development of a granular structure. The material is very hard when dry, very compact when moist, and very plastic and moderately sticky when wet. Worm casts are absent, and plant rootlets largely follow the crevices between structure fragments.
3. 24 to 48 inches, calcareous clay containing a very few small soft carbonate of lime concretions. The color is chocolate brown or dark reddish brown, the red increasing with depth and merging with the color of the layer below. The division between this and the overlying layer is placed at the depth of reaction with hydrochloric acid. The clay is very hard when dry, very compact when moist, very plastic and moderately sticky when wet, and extremely tough when nearly dry. No well-defined structure or breakage is evident.
4. 48 to 68 inches, noncalcareous clay with a very few fine soft carbonate of lime concretions. The material is reddish yellow or dull red when moist and brownish red when dry. The material is moderately hard when dry, moderately compact when moist, and moderately plastic

when wet. When dry it breaks into irregular clods about one-half inch in diameter. In some places in the lower 4 inches of this layer, there is also a faint dark-colored film on the outsides of the small clods, apparently consisting of organic matter. The material in the lower part of this layer is somewhat tubular, similar to that in the layer below.

5. 68 to 84 inches, the layer of carbonate concentration. Approximately 60 percent of the volume consists of roughly spherical aggregations of lime carbonate ranging from one-half inch to 1½ inches in diameter. These concretions are yellowish white or creamy white, whereas the rest of the material is light-brown or reddish-buff highly calcareous clay. The material in this layer is slightly hard when dry, friable when moist, and slightly plastic and slightly sticky when wet. The whole layer is filled with a network of open fine tubular channels about 0.01 inch in diameter and of undetermined length. The change to the underlying parent material is gradual. The heaviest concentration of carbonate of lime lies between depths of 68 and 74 inches. No gypsum is apparent in this layer, and no induration has taken place.
6. 84 to 132 inches +, the parent material of light-brown or reddish-buff highly calcareous clay which is friable when moist and slightly hard when dry. About 15 percent of the volume consists of small soft white lime carbonate aggregations about one-half inch in diameter. There seem to be pockets and layers of higher lime carbonate content. Except for the variation in carbonate concentration, the material in this layer is very uniform.

PECOS SERIES

The Pecos soils have dark-brown to black surface soils with chocolate-brown or chocolate-red subsoils. Calcium carbonate, gypsum, and alkali are all rather abundant in the soil material. The soils occur in alluvial lands along the Pecos River and are developed over sediments that have been washed from the Plains deposits and "Red Beds" by flood waters and have been deposited along the Pecos River. The reddish color of the subsoils is doubtless the original color of the "Red Beds" sediments.

Established in the west-central reconnaissance of Texas, 1922 (*13*)

PECOS LOAM

The Pecos loam is a heavy, loamy soil covering great areas of the prairie land representing the uppermost terrace of the basic deposits of the Quaternary age. The deposits also extend to the Pecos River along its terraces. The virgin soil, to various depths, is of recent aeolian origin. Soils under irrigation have received a fresh deposit of fine sediment of variable thickness.

The native vegetation consists of grama grass, small scattered mesquite, a number of weeds, and a few cacti.

Collectors—C. W. Botkin and W. G. Harper.

Location—Near Carlsbad, Eddy County, N. Mex., sec. 21, T. 22 N., R. 27 E.

Climate—Mean annual rainfall 14.07 inches; mean annual temperature 62.7° F.

A. Virgin soil, not under irrigation.
   1. 0 to 9 inches, slightly laminated calcareous loam. Dark olive brown with reddish or pinkish tinge. Very slightly firmed or cemented calcareous loam, a shade darker when moist.
   2. 9 to 18 inches, color and structure the same as loam above, many fine plant roots, worm casts, and larvae.
   3. 18 to 34 inches, same base color as above but contains small flecks or soft nodules of calcium carbonate. The flecks are grayish and the pulverized soil is grayish and more gray than horizon above. Nodules 1 to 3½ mm in size. Loam, structure same as above, many plant roots, and a few worm casts and larvae.

4. 34 to 48 inches, differs from horizon above in having fewer calcium carbonate spots. Lime seems to be more finely divided and color is evenly distributed. When wet, the color is light olive brown, when dry, olive brown with pinkish tinge. Plant roots less numerous, a few worm casts and larvae. Loam.
5. 48 to 71 inches, zone of highest lime accumulation. Light olive brown with slight pink tinge and containing many grayish splotches and nodules of calcium carbonate. Some nodules 1 cm in diameter. Very few roots or casts. Slightly cemented by calcium carbonate and probably has a single-grained structure. Loam.
6. 71 to 83 inches, transitional horizon between above and parent material. No roots or nodules, slight infiltration of calcium carbonate. Light olive brown with decided reddish tinge. Loam.
7. 83 to 95 inches, light olive-brown, highly calcareous, friable, light loam. No calcium carbonate accumulations.

B. Soil irrigated since 1896, near A above. Land is in alfalfa, good growth, 2 feet high at time of collection.
1. 0 to 9 inches, firm but friable, calcareous loam. Slightly darker than the horizon below.
2. 9 to 18 inches, reddish brown when wet. Olive brown with slight pinkish or reddish tinge when dry. No darkening due to humus is apparent. Friable calcareous loam with some silica, no mica. The sandy material consists of fine and very fine sand.
3. 18 to 35 inches, same as above with some flecks of $CaCO_3$.
4. 35 to 47 inches, same as above.
5. 47 to 53 inches, same but more lime giving grayish cast, pinkish gray.
6. 53 to 64 inches, same but with slightly more lime. A few nodules of $CaCO_3$.
7. 64 to 82 inches, zone of high lime accumulation. Many nodules. Structure and texture same as above.
8. 82 to 90 inches, transitional zone. Much like parent material but with some lime accumulation. Very friable sandy loam, pinkish gray.
9. 90 to 101 inches, parent material, like that above in color and texture; some water-worn gravel below this horizon but mixed in loam. Roots in all horizons, worm casts less than in A above. All very friable.

PIMA SERIES

The soils of the Pima series are of dark-brown or dark grayish-brown color, often having a slight reddish or rich chocolate-brown tint. The subsoils are of similar or of lighter and more grayish color, particularly where highly calcareous. Both surface soil and subsoil are usually well supplied with lime. The subsoil is similar in texture to the surface soil or consists of variably textured stratified sediments without cementation or other alteration in place through leaching or weathering. The series is developed over recent alluvial deposits derived from a variety of rocks and occupies stream-flood plains and low recent terraces. The surface is generally smooth and level. The soils are frequently subject to overflow and are at times otherwise poorly drained. Accumulation of alkali salts is common, but the soils are, however, quite easily reclaimed by drainage and flooding. The soils of this series are similar to the Gila soils in origin, mode of formation, and topography, but are differentiated by the dark color of the surface horizon.

Established in Middle Gila Valley area, Ariz., 1917 (*22*).

PIMA CLAY ADOBE

The Pima clay adobe has been previously described by Nelson and Holmes (*33*) as Gila clay adobe. The Pima clay adobe consists of a grayish-brown to dark-brown, heavy, compact clay varying in depth from 6 inches to 4 feet. The subsoil, extending to a depth of 6 feet or more, is composed of irregularly stratified material varying in texture from sand to silty clay loam. The surface soil is usually very heavy and of compact adobe structure which makes tillage difficult and seriously interferes with the downward passage of water although the underdrainage is good. This is due to the stratified sandy deposits of river alluvium which form the subsoil. The tight compact adobe covering the sandy deposits is found in irregular bodies throughout the Mesilla Valley wherever conditions favored the deposition of the finest sediments carried in suspension by floods of the Rio Grande. The sediments are derived from rocks of Tertiary age. Most of the soils of the river-flood plain have been modified by wind erosion. Soils under irrigation have accumulated 2 to 6 inches of fine sediment from the irrigation waters.

All the samples below were collected from a soil type that is considered very young and the horizons or changes within the profiles are not developed as are those in the samples taken from the Pecos sandy loam near Carlsbad.

The native vegetation consists of cottonwood, mesquite, tomillo, willow, arrowweed, and native grasses.

Collectors—C. W. Botkin and W. G. Harper.

Location—New Mexico Agricultural College Farm near Mesilla Park, Dona Ana County, N. Mex.

Climate—Mean annual rainfall, 8.50 inches; mean annual temperature, 61.2° F.

A. Virgin soil, not under cultivation. Land partly covered by wild grasses and weeds.
   1. 0 to 9 inches, dark chocolate-brown clay or clay adobe. Highly calcareous. Many plant roots. Breaks into irregularly shaped, angular clods. Many irregular checks at surface.
   2. 9 to 29 inches, same as above.
   3. 29 to 41 inches, lighter in texture and color than above. A silty clay, does not check as much as horizons above.
   4. 41 to 45 inches, clay very much like the surface. Slightly more reddish.
   5. 45 to 49 inches, rich-brown, heavy fine sandy loam, highly calcareous.
   6. 49 to 54 inches, rich-brown, loamy fine sand with some fine gravel. Mildly to moderately calcareous.
   7. 54 to 84 inches, somewhat stratified fine sands with some gravel. Strata light brown, grayish brown, and slightly reddish brown. The upper part effervesces slightly with dilute HCl, foam visible. In lower part foam not visible but the action can be heard.

B. Soil under irrigation since 1894, near A above. Land in sugar beets, has been in grain, orchards, and other crops since establishment of the experiment station.
   1. 0 to 9 inches, dark chocolate-brown, highly calcareous, clay or clay adobe.
   2. 9 to 21 inches, same as above.
   3. 21 to 48 inches, same as this horizon in A above.
   4. 48 to 51 inches, clay much the same as horizon 4 in A above.
   5. 51 to 58 inches, rich-brown fine sand, higher in $CaCO_3$ than horizon below.
   6. 58 to 89 inches, loose mildly calcareous fine sand and sand.

ROUGH STONY LAND[1]

Rough stony land consists of steep, rough, and stony areas that have no present agricultural value. It includes various shallow soils occupying buttes and the lower slopes of mountains. The soils are derived almost entirely from granite, gneiss, mica schist, and associated rocks. One of these soils derived from granite was taken for examination. There are numerous outcropping ledges

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[1] Abstracted from the soil survey report of the Middle Gila Valley, Ariz.(*25*).

and loose stones. Rock fragments of all sizes are abundant, especially around the lower slopes of the buttes and mountains.

The vegetation over the greater part of the rough stony land is sparse and of low grazing value. It consists mainly of cacti of various kinds, creosotebush, and several less important plants.

KELVIN SERIES

The Kelvin soils are immature soils derived from granite. They have not previously been named, therefore the name "Kelvin" is tentatively assigned to them for purposes of convenience. There is a considerable area of rolling hills of granite a few miles east of Florence and near Kelvin, Ariz., within which the samples were taken. Although chemical degradation of granite rocks is slow under desert conditions, it has been sufficient to produce in many places an accumulation of soil to a depth of 8 to 20 inches. The surface soil is probably in part wind-blown. The vegetation is sparse, consisting mostly of cacti and yucca. The following profiles were collected by W. G. Harper.

Climate—Mean annual rainfall, 10.46 inches; mean annual temperature, 68.8° F.

KELVIN GRAVELLY LOAM

Location—Sample taken on ridge top 16 miles east of Florence, Ariz., on Kelvin road.

1. 0 to 4 inches, light reddish-brown loam.
2. 4 to 8 inches, reddish-brown gritty loam.
3. 8 inches+ , bedrock of granite.

KELVIN SANDY LOAM

Location—Sample taken on ridge top 22½ miles east of Florence, Ariz., on Kelvin road (road cut).

1. 0 to 1 inch, brown gravelly loam.
2. 1 to 8 inches, brown gritty loam or clay loam.
3. 8 to 20 inches, light-brown decomposing granite.
4. 20 inches+, grayish-brown granite.

METHODS OF EXAMINATION

The methods used in the examination of the soils and colloids are essentially these described by Brown, Rice, and Byers (*7*). The mechanical analyses were made by the pipette method described by Olmstead, Alexander, and Middleton (*35*). Included with the mechanical analyses are determinations of organic matter by hydrogen peroxide. The method is not precise, and therefore when but small quantities of organic matter are present with considerable soluble inorganic matter the organic matter is not reported. The chemical analyses were made according to the procedure described by Robinson (*39*). The organic matter was determined according to Alexander and Byers (*1*). The colloids were extracted from the soils with the aid of the supercentrifuge, essentially as described by Brown and Byers (*6*). No agent was used to assist dispersion in water. An adequate amount of colloid was obtained. From 500 to 2,000 g of soil were kneaded to a plastic mass and dispersed by hand rubbing in 10 gallons of distilled water. Sandy samples were initially dispersed with a mechanical stirrer described by Holmes and Edgington (*24*). The resulting suspension was centrifuged at a rate of 17 seconds per liter at a speed of 17,000 revolutions per minute (diameter of bowl, 4 inches). Very few of the particles remaining suspended exceeded 0.3μ in diameter. The sediment in the centrifuge bowl was redispersed in the filtrate from the centrifugate. In most cases the centrifugate was passed through the centrifuge a second time before filtration to make sure no large particles remained suspended. The resulting colloid was collected on Pasteur-Chamberland filters. The process was repeated (usually four times) until a considerable portion of the total colloid in the soil was obtained. The final product was air-dried on filter papers placed on a porous plate. The filter paper was easily stripped from the dry colloid after it was moistened.

The colloids were analyzed by the same methods employed for the soils. In calculating the water of combination the carbon dioxide content, as well as the organic matter, was subtracted from the loss on ignition. Other calculated relations are noted in the tables.

The pH values of the soils (air-dried) were determined by the use of the hydrogen electrode as described by Bailey (*5*). The approximate salt content was determined by use of the electrolytic bridge, as described by Davis (*20*).

The water vapor adsorption of the colloid was determined by the method described by Robinson (*38*) and by Middleton (*30*).

The data are presented in tables for each soil examined, together with a brief discussion of each table. These tables are followed by a series of tables which present certain data which are derived from the analytical results.

ANALYTICAL RESULTS

SCOBEY LOAM

The Scobey loam is the most northerly of the group of soils examined. A detailed discussion of its morphology and genesis is given by Kellogg (*26*). The data obtained by mechanical anlayses (table 1) indicate a fairly uniform texture throughout the profile. The sand fractions total 30 to 40 percent, indicating good underdrainage in this soil. The two surface horizons contain 5 to 10 percent more silt than those below. The clay and colloid content increase until the parent material is reached. While it is apparent that fine material is removed from the surface soil, relatively little illuviation has occurred. It seems clear that the removal processes have been wind or water erosion.

TABLE 1.—*Mechanical analyses of Scobey loam* [1]

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25) mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10660	1	0 -1½	0.6	3.1	6.2	17.2	9.1	37.7	21.0	16.0	4.6
10661	2	1½-6	.9	3.4	6.8	19.1	9.8	35.2	21.3	18.4	3.1
10662	3	6 -13	.4	3.2	6.8	20.0	9.8	27.2	30.4	26.0	1.9
10663	4	13 -20	.8	2.6	6.0	15.8	10.2	26.8	36.6	30.3	1.0
10664	5	20 -24	.9	2.2	3.9	10.5	10.0	26.7	44.7	34.2	.8
10665	6	24+	1.5	2.2	3.7	10.6	10.9	29.8	40.6	32.2	.3

[1] Determinations by H. W. Lakin and T. M. Shaw.

The chemical analyses of the whole soil, as shown in table 2, also indicate that there has been considerable movement of material from the upper horizons. The silica decreases with depth in the profile as the clay content increases the effect of sand and silt on the chemical composition. The organic matter and the carbonates are not present in sufficient amounts to conceal this relation. There is a change in the profile at a depth of 13 inches owing to the presence of carbonates. Above this depth the soil is acid. Soluble salts have collected in the parent material. The percentages of alumina and of potassium and sodium oxides suggest the presence of a relatively large amount of undecomposed feldspar. The minor constituents are quite constant throughout the profile except those associated with the organic matter. The carbonate indicated in horizons 5 and 6 is certainly dolomitic.

TABLE 2.—*Chemical analyses of Scobey (Charbon) loam* [1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10660	1	0 -1½	74.26	2.78	10.84	0.82	1.43	2.03	1.11	0.48
10661	2	1½-5	72.66	3.09	12.54	.78	1.14	2.12	1.19	.64
10662	3	5 -13	73.38	3.77	12.41	1.14	1.29	2.10	1.08	.64
10663	4	13 -20	68.14	4.52	13.09	1.69	2.32	2.02	.97	.58
10664	5	20 -24	57.44	4.10	11.38	2.64	9.77	1.79	.91	.49
10665	6	24+	58.19	4.30	12.90	3.25	8.44	1.99	1.07	.50

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [2]	CO_2 [3]	N	pH	Soluble salts
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
10660	0.08	0.21	0.15	6.71	100.90	3.60	0.00	0.23	5.7	420
10661	.07	.16	.12	5.40	99.81	2.50	.00	.16	5.8	<208
10662	.06	.15	.11	4.01	100.04	.99	.00	.10	5.7	<208
10663	.07	.22	.12	6.00	99.74	1.42	1.03	.10	8.0	500
10664	.06	.23	.12	11.89	100.82	1.34	7.62	.10	8.5	700
10665	.07	.25	.14	9.52	100.68	.40	6.52	.04	8.8	1,280

[1] Determinations by G. J. Hough except pH and soluble salts.
[2] By combustion method ($CO_2 \times 0.471$).
[3] CO_2 of the carbonates.

SCOBEY LOAM COLLOID

The colloid analyses (table 3) show a greater uniformity of composition than do those of the whole soil. The effect of larger sized particles, consisting chiefly of quartz, had been eliminated. The colloid from each horizon was extracted by identical treatment yet the quantity of colloid obtained shows considerable variation. The fourth column of table 3, and all subsequent tables of colloid analyses, gives the percentage of colloid obtained with reference to the total quantity indicated as present by mechanical analyses. The relatively low calcium oxide in the fifth and sixth horizons, compared with the carbon dioxide present, indicates that even in the colloid the dispersed carbonate is somewhat dolomitic. Although the colloid analyses do show a marked degree of uniformity of composition the relations are somewhat masked by the variations in carbonate and organic-matter content. Thus the increase of silica, iron oxide, and alumina in the third and fourth horizons is more apparent than real, since the first and second horizons are high in organic matter and the fifth and sixth are high in carbon dioxide content. For these and similar reasons the analytical relations are more sharply defined by the ratios given in table 4.

TABLE 3.—*Chemical analyses of Scobey loam colloid*

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10660	1	0 -1½	24	47.25	9.02	18.03	2.12	0.75	2.35
10661	2	1½-5	37	47.93	9.02	21.33	2.34	.69	2.65
10662	3	5 -13	55	50.29	10.38	21.07	2.99	.90	2.10
10663	4	13 -20	47	50.85	9.62	21.42	3.18	1.40	1.90
10664	5	20 -24	36	45.66	9.62	18.58	3.11	6.75	1.73
10665	6	24+	46	47.02	9.55	17.85	4.15	6.24	1.80

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[1]	CO_2[2]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10660	0.11	0.55	0.17	0.43	0.32	19.60	100.70	10.88	0.06	0.76
10661	.15	.52	.14	.30	.25	15.30	100.72	7.56	.10	.50
10662	.05	.51	.06	.17	.17	11.97	100.68	3.61	.06	.25
10663	.04	.57	.06	.18	.13	10.94	100.51	2.80	.05	.19
10664	.05	.52	.06	.20	.13	13.92	100.35	2.74	4.59	.20
10665	.09	.55	.06	.14	.13	12.86	100.44	1.32	4.76	.10

[1] Determined by combustion method ($CO_2 \times 0.471$).
[2] CO_2 of the carbonates.

The derived data (table 4) clearly indicate the degree of uniformity of the composition of the inorganic colloid. There is, as is usual, a somewhat higher ratio of silica to sesquioxides and of silica to alumina in the surface layer. As compared with the second layer, the difference, though not large, cannot be attributed to the removal of iron oxide from the surface soil, since in this case the relative quantity of iron oxide in the surface soil is slightly greater than in the layer immediately beneath. In the third layer, however, is found a faint indication of podzolization through the somewhat lowered silica-iron oxide ratio and the change in the iron oxide-alumina ratio. The differences are so small that dogmatic assertion is not warranted. One might be inclined to consider the high silica in the surafce layer to be residual silica from organic ash.

TABLE 4.—*Derived data: Scobey loam colloid*

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid[3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$[1]	$\frac{SiO_2}{H_2O}$[2]		
		Inches							*Percent*	*Percent*
10660	1	0 -1½	3.37	13.90	4.47	.320	8.58	1.37	8.66	11.58
10661	2	1½-5	3.00	14.10	3.81	.270	7.39	1.52	7.64	10.23
10662	3	5 -13	3.05	12.73	4.04	.315	7.48	1.46	8.30	10.71
10663	4	13 -20	3.07	13.56	3.97	.293	6.83	1.47	8.09	10.69
10664	5	20 -24	3.13	12.56	4.17	.331	6.73	1.58	6.59	9.92
10665	6	24+	3.26	13.04	4.34	.333	6.15	1.55	6.78	10.81

[1] Carbonates deducted.
[2] Combined water plus water equivalent of the bases.
[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.

The high silica-base ratio of the surface soil, coupled with its progressive decrease with depth, is normal and is the effect to be expected from eluviation. It is not, however, to be assumed that the leached bases are deposited at lower levels; their more probable fate is removal by surface drainage. The increased base content at lower levels is rather to be taken as partly owing to decreased weathering. This is also in harmony with the increased silica-sesquioxide and silica-alumina ratios at lower levels.

The silica-water ratios and the combined-water percentages offer qualitative evidence that removal of bases is accompanied by replacement by water. The combined water of the soil acid (p. 16) is about 1 percent greater in the surface layer than in the remainder of the profile. It has already been mentioned that this quantity is particularly subject to inaccuracy of calculation when the organic content is high.

The derived data of the profile, despite the variations mentioned, show a degree of uniformity of composition which is scarcely to have been expected except that there exists a colloid complex of definite composition and one perhaps dominated by the presence of a single substance.

SPEARFISH SILT LOAM

The Triassic shales are exposed in a narrow belt around the Black Hills of South Dakota. These shales are brilliantly red. The Spearfish soil is developed on these typically red shales which have not been greatly modified by weathering since their exposure. It is the only red soil in the group discussed in this bulletin. The climatic conditions are such as do not naturally produce red soils. The color is therefore due to the parent material.

The data obtained by mechanical analyses are shown in table 5. In marked contrast with the Scobey, the sands, except at the surface horizon, scarcely exceed 5 percent which indicates poor underdrainage. The permeability, however, is favored by the flocculation of colloid effected by the high calcium content of the soil and colloid (tables 6 and 7). The distribution of clay and colloid in this profile is quite unusual. The relations indicate that the profile has been comparatively undisturbed, except at the surface, since the original deposition of these water-laid shales.

TABLE 5.—*Mechanical analyses of Spearfish silt loam* [1]

Sample no.	Horizon	Depth	Fine gravel (2–1 mm)	Coarse sand (1–0.5 mm)	Medium sand (0.5–0.25 mm)	Fine sand (0.25–0.1 mm)	Very fine sand (0.1–0.05 mm)	Silt (0.05–0.005 mm)	Clay (0.005–0 mm)	Colloid (0.002–0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-1086	1	0-12	0.2	1.4	2.6	7.0	15.2	39.8	30.6	26.3	2.6
B-1087	2	12-24	.1	.3	.3	.9	4.4	53.4	39.8	24.0	.5
B-1088	3	[2] 28-42	.2	.7	.7	1.0	3.5	56.9	36.6	20.5	.1
B-1089	4	[2] 60-72	.3	.7	.4	.8	2.2	56.7	35.0	17.5	.6

[1] Determinations by H. W. Lakin and T. M. Shaw.

[2] A portion of the profile omitted.

Although the chemical analyses of the soil (table 6) are profoundly affected by the high percentage of dolomitic limestone the general relationships are not completely obscure. A difference of about 20 percent in silica reflects the higher percentage of sands in horizon 1 over those below which are much alike. The sesquioxides and potash increase with depth in the profile. In the face of a decreasing amount of colloid (table 5) in the lower horizons this fact indicates that these components are removed to some extent by eluviation from the comparatively more weathered surface layers. Also, the more soluble products of weathering and those present in the parent material have been removed from the upper horizons although the carbonates have not. The presence of sulphates and carbonates in considerable quantities, together with the presence of large soluble salt content in the parent material, indicates that the pH value of the fourth layer is the resultant effect of the presence of carbonates and of gypsum.

TABLE 6.—*Chemical analyses of Spearfish silt loam* [1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-1086	1	0-12	68.71	3.51	10.17	2.02	3.42	2.40	0.44	0.54
B-1087	2	12-24	46.58	3.69	10.64	6.25	12.68	3.50	.19	.53
B-1088	3	[2] 28-42	47.49	4.02	11.10	7.45	9.67	3.71	.22	.59
B-1089	4	[2] 60-72	44.04	4.21	11.21	7.47	10.15	4.04	.28	.59

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [3]	CO_2 [4]	N	pH	Soluble salts
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
B-1086	0.06	0.13	0.14	8.58	100.10	3.26	2.79	0.20	7.7	900
B-1087	.08	.11	.13	16.13	100.47	.50	13.01	.06	8.1	900
B-1088	.09	.11	.08	14.98	99.51	.20	12.40	.03	8.4	820
B-1089	.10	.10	3.86	13.38	100.03	.20	10.89	.03	7.8	13,240

[1] Determinations by Glen Edgington except pH and soluble salts.
[2] A portion of the profile omitted.
[3] By combustion method ($CO_2 \times 0.471$).
[4] CO_2 of the carbonates.

If the necessary allowances be made for the presence of organic matter and for assumed presence of dolomite, the residual percentages of magnesia become 0.8, 0.4, 2.5, and 3.9, while for calcium oxide they are 1.9, 6.3, 2.5, and 0.8. These quantities are reasonably close to normal for soils of this type free from carbonates. It seems apparent therefore that the carbonates are highly dolomitic. Low sodium oxide throughout the profile as compared with the potash present suggests the presence of potash rather than sodium feldspars. This is confirmed by petrographic examination of the separates.

The colloid analyses (table 7) indicate an apparently striking diversity of composition, even when allowance is made for the presence of carbonates and organic matter. Alumina, magnesia, and potash have been removed from the surface layer to some extent but have not been accumulated at lower levels. There is no definite evidence whether or not the dispersed carbonates are dolomitic. Presumably they are not. The exceptionally high magnesium content, particularly at lower levels, together with the low content of carbon dioxide, may be taken to indicate that the greater portion of the magnesium is not only not associated with carbon dioxide, but that it is a portion of unweathered or but partially weathered silicate minerals. (See also discussion of table 8.) Petrographic examination shows the presence in the sands of abundant micas, particularly biotite, and minor quantities of garnet, hornblende, pyroxene, and chlorite. This may not be a general characteristic of Spearfish shales, for Richardson (*37*) has reported very small amounts of magnesia-bearing minerals in Spearfish shales from New Castle and Spearfish, S. Dak.

TABLE 7.—*Chemical analyses of Spearfish silt loam colloid*

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-1086	1	0–12	35	45.29	6.40	22.91	4.08	3.34	2.33
B-1087	2	12–24	43	43.46	6.18	24.02	8.89	2.41	4.07
B-1088	3	[1] 28–42	66	44.00	6.30	24.73	10.51	.91	4.43
B-1089	4	[1] 60–72	53	44.15	6.29	25.13	10.34	.68	4.05

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[2]	CO_2[3]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-1086	0.25	.54	0.09	0.25	0.27	14.21	99.96	6.84	1.54	0.38
B-1087	.51	.54	.10	.16	.27	9.22	99.82	1.56	1.62	.11
B-1088	.22	.53	.10	.14	.35	7.80	100.02	.75	.37	.08
B-1089	.42	.64	.14	.15	.17	7.51	100.27	.70	.24	.07

[1] A portion of the profile omitted.
[2] Determined by combustion method ($CO_2 \times 0.471$).
[3] CO_2 of the carbonates.

The derived data (table 8) show in a very definite manner the essentially constant composition of the inorganic portion of the colloid. The surface horizon has a somewhat higher silica-sesquioxide and silica-alumina ratio than is found at lower levels but it may be noted that the differences are less sharp than in the Scobey colloid (table 4). This accords with the suspicion that the high silica is partly due to plant residual silica. Both the silica-sesquioxide and silica-alumina ratios of the profile are low. Indeed they are lower than any other of the 13 profiles considered in the present discussion. There may be discerned two possible reasons for this fact. The iron oxide is apparently not a part of the silicate complex. This is assumed not only because of the color of the parent shale but is indicated also by the exceeding constancy of the silica-iron oxide and iron oxide-alumina ratios. If the colloid be heated to about 900° C. from 1 to 2 hours the color fades to a light buff. The low silica-alumina ratios appear to be owing to the presence in the colloid of exceptionally high magnesium oxide in the silicate complex. In the light of the data submitted by Robinson, Edgington, and Byers (*40*) with reference to the soils derived from rocks high in magnesia the Spearfish should be an infertile soil, if infertility be due to adverse calcium-magnesium ratios. The available data do not warrant positive assertion of low productivity of this soil since little of it is used agriculturally.

TABLE 8.—*Derived data: Spearfish silt loam colloid*

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid[3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$[1]	$\frac{SiO_2}{H_2O}$[2]		
		Inches							*Percent*	*Percent*
B-1086	1	0-12	2.64	18.73	3.35	0.179	4.56	1.38	6.83	10.79
B-1087	2	12-24	2.63	18.62	3.08	.164	2.42	1.14	6.04	12.01
B-1088	3	[4] 28-42	2.59	18.53	3.01	.162	2.29	1.06	6.68	12.63
B-1089	4	[4] 60-72	2.56	18.55	2.97	.160	2.29	1.07	6.57	12.33

[1] Carbonates deducted.
[2] Combined water plus water equivalent of the bases.
[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.
[4] A portion of the profile omitted.

It is probably because the greater part of the magnesium is associated with the silicate complex, namely, as a portion of the acid radical, that the silica-base ratio is so low, particularly in the lower strata, and the combined water of the soil acid is so exceptionally high in the lower strata.

This soil is exceptionally immature in its profile development, in the morphological sense, even for semiarid soils, yet its colloid content indicates a considerable degree of weathering. A very considerable part of this weathering has doubtless occurred before the parent formation was laid down and for this reason the influence of parent material on the soil characteristics is more marked than in any of the soils examined in this investigation. Richardson (*37*) has asserted that the "Red Beds" of the Black Hills were largely derived from a well-weathered residual red soil previous to deposition.

BADLANDS SILT LOAM

This material was selected for study partly by reason of its peculiar origin and location and partly because it appeared to offer a striking contrast with the Spearfish soil which lies only about 50 miles to the northwest and the Pierre loam which lies to the west, north, and east of the Badlands. The profile samples were taken from a small flat-topped butte about 20 feet in height. This soil, like the Spearfish, is comparatively immature.

The mechanical analyses (table 9) indicate in this profile a greater degree of permeability to water than is normal for the Brule clay and perhaps accounts in part for the existence of the butte. The top layer of loose material is only about an inch in thickness and the organic matter in it consists largely of grass roots. There is evidence of some accumulation of colloid in the third layer and this probably marks the zone of maximum mean penetration of water (cf. table 10). The surface layer is obviously freed in part from the finer material.

TABLE 9.—*Mechanical analyses of Badlands silt loam* [1]

Sample no.	Horizon	Depth	Fine gravel (2–1 mm)	Coarse sand (1–0.5 mm)	Medium sand (0.5–0.25 mm)	Fine sand (0.25–0.1 mm	Very fine sand (0.1–0.05 mm)	Silt (0.05–0.005 mm)	Clay (0.005–0 mm)	Colloid (0.002–0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-1041	1	0– 1	0.2	0.4	0.5	3.3	30.4	47.8	14.5	12.6	2.1
B-1042	2	1–12	.1	.2	.2	2.0	22.5	51.8	21.8	20.3	1.1
B-1043	3	12–30	.1	0	.1	1.0	11.6	52.4	33.4	26.1	.6
B-1044	4	[2] 72–84	0	0	.1	2.5	36.0	41.8	19.1	17.8	[3] 0

[1] Determinations by H. W. Lakin and T. M. Shaw.
[2] 42 inches of the profile omitted.
[3] Organic matter not in excess of 0.4 percent.

TABLE 10.—*Chemical analyses of Badlands silt loam* [1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-1041	1	0– 1	71.50	2.42	11.50	0.94	2.78	2.77	1.49	0.60
B-1042	2	1–12	72.42	2.71	12.49	.96	2.48	2.79	1.53	.57
B-1043	3	12–30	60.79	2.79	12.13	1.43	8.73	2.71	1.59	.55
B-1044	4	[2] 72–84	67.38	2.50	11.25	1.10	6.62	2.84	1.74	.52

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [3]	CO_2 [4]	N	pH	Soluble salts
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
B-1041	0.08	0.16	0.11	5.65	99.80	2.08	0.77	0.15	7.7	820
B-1042	.08	.14	.12	3.51	99.80	1.56	.68	.11	8.2	1,100
B-1043	.09	.16	.11	8.86	99.94	.69	5.58	.06	8.6	3,900
B-1044	.09	.16	.10	5.85	100.15	.14	4.22	.02	8.6	4,600

[1] Determinations by Glen Edgington except pH and soluble salts.
[2] A portion of the profile omitted.
[3] By combustion method (CO_2 x 0.471).
[4] CO_2 of the carbonates.

The transfer of finer material to lower levels is also indicated by the soil analyses. When correction for organic matter and carbonates is made the silica percentages for the profile are 75.00, 75.00, 70.20, and 74.50. The increase of finer material in the third horizon significantly lowers the silica content. A study of the data on the carbonates indicates little or no dolomitic material but reveals a definite zone of carbonate accumulation in the third horizon. The constancy of the sodium and potassium content throughout the profile indicates a low degree of weathering of the feldspars. The pH values and the soluble salt content indicate leaching of soluble salts from the upper portion of the profile but no accumulation of gypsum within it.

The analytical data for the soil colloid (table 11) offer but few points for consideration which are not better brought out by the derived data. The usual decrease in organic matter with depth is observed. The carbonate present in the soil suffers dispersion to a large extent and is sharply increased in the zone of carbonate accumulation.

TABLE 11.—*Chemical analyses of Badlands silt loam and bentonite colloids*

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Precent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-1041	1	0-1	33	54.41	6.14	16.09	3.51	1.98	2.70
B-1042	2	1-12	46	54.55	5.96	18.27	3.39	3.44	2.04
B-1043	3	12-30	54	52.99	6.07	16.70	3.70	6.29	2.72
B-1044	4	[1] 72-84	51	58.25	6.70	17.15	4.03	2.24	2.61
154 [2]				60.49	4.00	23.24	2.48	.53	.22

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [3]	CO_2 [4]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-1041	0.27	0.66	0.15	0.30	0.29	12.85	99.95	7.48	0.14	0.46
B-1042	.36	.58	.09	.18	.25	10.69	100.40	3.52	1.22	.21
B-1043	.44	.66	.08	.22	.17	10.18	100.22	1.35	3.65	.08
B-1044	.33	.74	.07	.31	.05	7.68	100.16	1.32	.17	.08
154 [2]	1.83	.32	.09	.04	.10	6.04	99.98	.54	.17	

[1] 42 inches of the profile omitted.
[2] Bentonite.
[3] Determined by combustion method ($CO_2 \times 0.471$).
[4] CO_2 of the carbonates.

The exceptionally high silica content of the colloid and the fact that the Brule clay is presumed to be high in bentonite content and volcanic ash (*19*, *34*), seemed to warrant a comparison of this colloid with a colloid from bentonite. The sample of colloid was extracted from a bentonite from near Belle Fourche, S. Dak. The analysis of this colloid is given in the last line of table 11.

The characteristic swelling of bentonite is not shown by the soil colloid. The most marked differences between the bentonite colloid shown by the analyses are in the base content and loss on ignition. Apparently the bentonite has been weathered from material high in soda feldspars while the soil colloid is derived from material high in potash. Petrographic examination of the soil separates reveals the presence of a high percentage of calcium and potash feldspars. It would appear that the differences in the physical behavior of the soil and bentonite colloids are due to the differences in bases present.

The derived data (table 12) show the usual relationships of the Pedocal colloids but in degrees markedly different from the soils which are closely related geographically. The silica-sesquioxide and silica-alumina ratios are higher than in any of the colloids of the present series or, indeed, of any soil colloids except one reported by Williams (*43*, *44*) on 2μ clay. The colloid of the Badlands is nearly white when free from organic matter and hence the iron oxide present must be regarded as a part of the silicate complex. In consequence the composition of the hypothetical colloid acid (see general discussion) is better indicated by the silica-sesquioxide than by the silica-alumina ratio. Nevertheless, the ratio (silica-sesquioxide) is above 4 throughout the horizon. If any soil colloid in the present list may be assumed to contain a montmorillonitic acid complex, this is it. In view, however, of the possible presence in the colloid of free silica of colloidal dimension and of feldspathic material but little hydrolyzed, such assumption is not warranted. These statements also are valid with reference to the bentonite colloid. The silica-total base ratios are fairly low for the soil colloid, and the higher ratio for the bentonite indicates the greater degree of leaching of the latter. The fact that the silica-water ratio is highest in the bentonite colloid and the surface layer of the soil may be assumed as indication of dehydration to greater degree as bases are replaced. This relation is also, of course, indicated by the values for the combined water of the soil acid.

TABLE 12.—*Derived data: Badlands silt loam and bentonite colloids*

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid[3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$[1]	$\frac{SiO_2}{H_2O}$[2]		
		Inches							*Percent*	*Percent*
B-1041	1	0–1	4.48	23.50	5.63	0.235	6.10	2.04	5.23	8.65
B-1042	2	1–12	4.20	24.10	5.03	.210	5.98	1.88	5.95	9.25
B-1043	3	12–30	4.36	23.10	5.37	.233	5.52	1.94	5.28	9.00
B-1044	4	[4] 72–84	4.61	23.05	5.76	.250	5.72	1.88	6.19	9.39
154[5]			3.92	35.00	4.42	.126	10.16	2.56	5.33	7.10

[1] Carbonates deducted.
[2] Combined water plus water equivalent of the bases.
[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.
[4] 42 inches of the profile omitted.
[5] Bentonite.

PIERRE CLAY

The Pierre clay is developed from Pierre shale (Cretaceous). The soil is of wide distribution in the areas adjacent to the Black Hills and reaches as far east as the Missouri River in South Dakota. The particular profile here reported is on the eastern edge of the soil area. It was selected because it is the soil in which the presence of selenium was first recognized as producing toxic vegetation. The quantities of selenium found in this profile are added to table 14. The soil is also of interest because in addition to selenium it contains arsenic, chromium, and vanadium. The quantities of these elements in a portion of a similar profile reported by Byers (*9*) are: Se, 2 p. p. m.; As_2O_3, 12 p. p. m.; V_2O_5, 465 p. p. m.; and Cr_2O_5, 133 p. p. m. The whole area of soils derived from the Pierre and Niobrara shales appears to contain selenium in varying quantities and to produce vegetation containing selenium (*10*).

The mechanical analyses of the Pierre clay (table 13) correspond to its field behavior. This soil is remarkably constant in composition and impervious to water. Nearly all the clay content is of colloidal character. There was but little of the parent shale present in the lowest layer of the profile as collected. The analyses of the surface layer indicates the removal of some of the finer material but no deposition at lower levels. The soil, though very dark at the surface, is nearly white after treatment with hydrogen peroxide. In some portions of the Pierre areas there are greater quantities of coarse material than are shown in the profile examined. This coarse material is in some places clearly derived from layers of the Pierre shale and in other places from residual fragments of glacial drift. This soil is locally known as "gumbo" and has a high shrinkage coefficient.

The cracks developed on drying doubtless facilitate the surface erosion which is very apparent over the whole area. The fineness of the soil and the excessive dry periods in the area also facilitate wind erosion.

TABLE 13.—*Mechanical analyses of Pierre clay*[1]

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-858	1	0- 8	0.3	0.2	0.1	0.5	1.5	26.6	68.0	57.4	2.1
B-895	2	8-18	.1	.1	.1	.4	1.4	24.4	72.4	58.9	.7
B-894	3	18-40	0	0	0	.4	1.4	23.1	74.6	60.1	[2] 0
B-857	4	40-60	0	0	0	.5	1.9	20.5	76.8	62.8	[2] 0
B-893	5	60-74	0	.1	.1	.6	1.6	18.0	76.7	61.8	[2] 0

[1] Determinations by H. W. Lakin and T. M. Shaw.
[2] Organic matter not present in excess of 0.4 percent.

The chemical analyses (table 14), like the mechanical analyses (table 13), indicate a soil of remarkably constant composition particularly so in the silica, alumina, and iron oxide content if allowance be made for variation in organic matter, carbonates, and sulphates. Calcium carbonate is present throughout the profile but shows evidence of accumulation between 18 and 60 inches. There is but slight evidence of the presence of dolomitic material. The pH values are normal for carbonate soils except in the lowest horizon, where it would appear that the presence of gypsum should lower the pH value. In the general run of the Pierre soils the zone of sulphate accumulation is nearer the surface than in the present profile (*10*). It may be remarked that while the zone of carbonate accumulation may be regarded as marking the maximum mean penetration of water, the zone of sulphate accumulation marks the maximum depth of penetration of moisture.

TABLE 14.—*Chemical analyses of Pierre clay*[1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-858	1	0- 8	46.01	5.57	13.40	1.44	13.60	1.93	0.50	0.70
B-895	2	8-18	45.85	5.72	13.05	1.62	15.84	1.75	.44	.61
B-894	3	18-40	42.85	5.63	12.65	1.60	18.17	1.69	.53	.56
B-857	4	40-60	41.57	5.79	13.29	1.70	17.20	1.92	.41	.59
B-893	5	60-74	42.32	5.84	13.44	1.64	17.39	1.98	.30	.61

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[2]	CO_2[3]	N	pH	Soluble salts	Selenium[4]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*	*Parts per million*
B-858	0.10	0.30	0.15	15.86	99.64	4.05	9.32	0.21	8.33	800	5.0
B-895	.10	.28	.16	14.65	99.87	2.58	11.25	.15	8.46	700	6.0
B-894	.09	[illegible]	.10	16.50	100.72	1.57	13.30	.09	8.30	760	4.0
B-857	.07	.33	.15	16.70	99.72	.64	13.18	.06	8.15	1,260	5.0
B-893	.10	.34	2.07	14.15	100.17	.82	11.29	.05	8.20	9,800	6.0

[1] Determinations by G. J. Hough except pH and soluble salts and selenium.
[2] Determined by combustion method ($CO_2 \times 0.471$).
[3] CO_2 of the carbonates.
[4] Determinations by K. T. Williams.

The chemical analyses of the colloid (table 15) also indicate the strikingly uniform character of the colloid. Indeed the only differences of any magnitude are the greater dispersibility of the calcium carbonate in horizon 6 as compared with the smaller degree of dispersion of the whole colloid. The relative phosphate dispersion is also greatest in horizon 6. This portion of the soil contains gypsum, which of course is not present in the colloid (table 14). The organic matter also seems to be more readily dispersible with increased depth.

TABLE 15.—*Chemical analyses of Pierre clay colloid*

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-858	1	0- 8	44	43.50	7.00	19.60	2.28	9.10	2.14
B-895	2	8-18	42	44.03	7.50	19.96	2.31	8.84	2.01
B-894	3	18-40	40	44.71	7.84	19.28	2.32	9.36	2.14
B-857	4	40-60	46	45.00	7.50	19.73	2.32	9.21	1.83
B-893	5	60-74	33	43.90	7.26	18.54	2.12	11.15	2.15

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[1]	CO_2[2]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-858	0.03	0.55	0.06	0.33	0.17	15.56	100.22	3.03	5.26	0.22
B-895	.03	.54	.06	.57	.09	14.14	100.68	2.96	4.98	.16
B-894	.12	.54	.05	.64	.10	13.52	100.62	1.93	5.32	.11
B-857	.11	.57	.06	.68	.11	12.67	100.69	1.38	5.46	.08
B-893	.09	.55	.04	.84	.16	13.69	100.49	1.26	7.21	.07

[1] Determined by combustion method ($CO_2 \times 0.471$).

[2] CO_2 of the carbonates.

The constancy of composition of the colloid throughout the profile, as shown by the derived data (table 16), is so exceptional that clear evidence of soil profile-forming agencies is nearly impossible to detect. It seems apparent that the decrease of fine material shown in table 13 has not increased the silica content of the upper portion of the profile. The small difference in silica-base ratios of the upper portion of the profile as compared with the lower portion may be considered as associated with the greater organic content of the upper portion. The steadily increasing values of the silica-water ratios and the decreasing values of the combined water of the soil acid may be inferred to mean that hydrolysis of the parent material minerals is greater in the upper portion. If this is the case then substitution of bases for hydrogen has occurred subsequent to hydrolysis. The character of the soil solution would seem to warrant this assumption (table 14).

TABLE 16.—*Derived data: Pierre clay colloid*

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid [3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$ [1]	$\frac{SiO_2}{H_2O}$ [2]		
		Inches							*Percent*	*Percent*
B-858	1	0–8	3.06	16.48	3.76	0.228	5.88	1.51	6.37	10.20
B-895	2	8–18	3.05	15.80	3.79	.240	5.90	1.57	6.20	9.86
B-891	3	18–40	3.26	15.10	3.92	.260	6.08	1.58	6.27	9.85
B-857	4	40–60	3.18	16.25	3.95	.243	6.41	1.72	5.83	9.25
B-893	5	60–74	3.21	16.04	4.01	.250	6.63	1.82	5.22	8.76

[1] Carbonates deducted.
[2] Combined water plus water equivalent of the bases.
[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.

KEITH SILT LOAM

The profile of the Keith silt loam included in this bulletin was reported on in a previous paper (7). It is here included, with added data, because of its geographical relation to the other soils under discussion. It is derived from loessial parent material under nearly the same rainfall as the other soils.

The mechanical analyses (table 17) indicate a fairly permeable soil and a small concentration of clay and colloid in the layers 3, 4, and 5. The greater concentration of sand and of silt in the upper portion (0–3½ inches) may in part be due to removal of fine material by wind and water erosion. Indeed it may be assumed that the dust-mulch layer will vary considerably from one dust storm to another.

TABLE 17.—*Mechanical analyses of Keith silt loam* [1]

Sample no.	Horizon	Depth	Fine gravel (2–1 mm)	Coarse sand (1–0.5 mm)	Medium sand (0.5–0.25 mm)	Fine sand (0.25–0.1 mm)	Very fine sand (0.1–0.05 mm)	Silt (0.05–0.005 mm)	Clay (0.005–0 mm)	Colloid (0.002–0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
9222	1	0 – ½	0.1	0.1	0.1	0.4	31.2	47.4	18.4	16.2	1.8
9223	2	½– 3½	.1	.2	.1	.4	26.8	47.8	22.8	20.0	1.2
9224	3	3½–14	.1	.1	0	.3	24.9	46.4	20.4	22.2	1.3
9225	4	14 –21	.1	.1	.1	.3	23.3	48.2	26.8	23.7	.5
9226	5	21 –33	0	.1	.1	.2	25.4	44.5	28.9	24.4	.1
9227	6	33 –40	0	0	0	.2	26.7	47.6	24.8	18.1	[2] 0
9228	7	40 –48	0	0	0	.2	29.3	48.6	21.2	15.1	[2] 0
9229	8	48 –72	0	0	.1	.2	30.5	50.4	18.3	13.2	[2] 0
9230	9	72 –96	0	0	.1	.2	31.6	49.8	17.6	13.2	[2] 0

[1] Determinations by H. W. Lakin and T. M. Shaw.
[2] Organic matter not present in excess of 0.4 percent.

The chemical analyses of the soil (table 18) indicate a zone of carbonate accumulation at a depth between 21 and 48 inches but probably not sufficient in amount to account for the removal from the surface horizons. The high percentages of potash and of sodium oxide indicate the presence of much undecomposed feldspars and a low degree of weathering. The relatively large concentration of soluble salts in the lower portion of the profile indicates very little, if any, percolation of water through the profile. There is but little evidence of the presence of dolomitic limestone. The chemical composition of the whole profile is very constant except in the respects mentioned.

TABLE 18.—*Chemical analyses of Keith silt loam*[1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
9222	1	0 - ½	72.82	3.04	10.86	1.06	1.86	2.48	2.35
9223	2	½- 3½	71.00	3.44	11.66	1.17	1.88	2.34	2.23
9224	3	3½-14	71.10	3.60	12.02	1.26	1.68	2.32	2.10
9225	4	14 -21	71.40	3.92	11.88	1.44	2.08	2.28	2.15
9226	5	21 -33	68.22	3.60	12.00	1.05	3.94	2.82	1.02
9227	6	33 -40	64.80	3.68	11.84	1.66	6.14	2.45	1.42
9228	7	40 -48	65.82	3.30	11.84	1.63	5.44	2.48	1.99
9229	8	48 -72	69.66	3.36	11.88	1.67	4.30	1.98	1.06
9230	9	72 -96	69.36	3.36	11.42	1.63	4.46	2.51	1.38

Sample no.	TiO_2	MnO	P_2O_5	Ignition loss	SO_3	Total	CO_2[2]	N	pH	Soluble salts[3]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
9222	0.60	0.02	0.10	4.63	0.16	99.98	0.05	0.14	7.4	580
9223	.60	.03	.11	5.55	.14	100.15	.03	.17	7.4	500
9224	.64	.03	.09	4.70	.18	99.92	.03	.12	7.6	400
9225	.64	.04	.09	3.90	.20	100.08	.10	.09	8.2	1,160
9226	.58	.03	.08	4.94	.24	100.02	1.48	.09	8.5	1,400
9227	.60	.05	.19	6.98	.15	99.96	3.83	.05	8.4	1,480
9228	.58	.05	.18	6.33	.30	100.00	3.04	.04	8.5	1,400
9229	.57	.07	.15	5.34	.23	100.27	2.42	.03	8.6	1,460
9230	.58	.05	.16	5.08	.10	100.15	2.24	.03	8.6	1,400

[1] Determinations (except pH and soluble salts) by J. G. Smith.
[2] CO_2 of the carbonates.
[3] Determined by bridge method.

The colloid composition (table 19) emphasizes the constancy of composition shown otherwise in the soil. Whatever movements of the colloid have occurred have not been accompanied by fractionation. The most marked variations are in the content of organic matter and of carbonates.

TABLE 19.—*Chemical analyses of Keith silt loam colloid*

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
9222	1	0 - ½	46	51.92	6.92	19.13	3.00	2.12	2.42
9223	2	½- 3½	46	51.45	6.92	18.61	2.64	2.21	2.41
9224	3	3½-14	79	51.80	7.13	19.67	3.07	2.70	2.33
9225	4	14 -21	76	53.00	7.22	20.49	3.37	1.93	2.34
9226	5	21 -33	87	47.80	6.19	17.88	3.51	7.59	2.16
9227	6	33 -40	89	43.60	5.39	16.62	3.31	11.92	1.82
9228	7	40 -48	68	46.00	5.77	17.58	3.39	9.72	1.91
9229	8	48 -72	92	49.50	6.45	19.09	3.48	6.54	2.12
9230	9	72 -96	90	52.61	6.98	19.75	3.52	3.63	2.21

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[1]	CO_2[2]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
9222	0.24	0.66	0.19	0.29	0.28	13.43	100.60	5.32	0.06	0.37
9223	.29	.71	.22	.36	.25	14.38	100.45	6.32	.09	.48
9224	.28	.72	.13	.22	.24	13.05	101.34	5.68	.00	.31
9225	.45	.67	.08	.11	.16	11.09	100.91	2.98	.22	.23
9226	.43	.54	.09	.27	.17	13.94	100.67	1.67	4.71	.16
9227	.37	.51	.11	.29	.15	16.70	100.79	1.75	8.34	.14
9228	.39	.52	.12	.23	.13	15.03	100.79	1.86	6.46	.08
9229	.38	.56	.11	.20	.13	12.33	100.80	1.21	3.56	.13
9230	.34	.66	.09	.21	.14	10.71	100.85	.80	1.32	.10

[1] Determined by combustion method (CO_2×0.471).
[2] CO_2 of the carbonates.

The derived data (table 20), as is usual, bring into clear relief the degree of variation of the composition of the inorganic colloid. The greater silica-sesquioxide and silica-alumina ratios of the topmost two layers, so notably absent in the Pierre clay colloid, are indicative of colloidal silica, but if it is present the quantity is small. The silica-total base ratio indicates a small degree of eluviation. Taken as a whole, all the data, and particularly the silica-water ratios, the combined water, and the combined water of the soil acid, indicate an inorganic colloid of constant composition (see general discussion).

TABLE 20.—*Derived data: Keith silt loam colloid*

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid [3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$ [1]	$\frac{SiO_2}{H_2O}$ [2]		
		Inches							*Percent*	*Percent*
9222	1	0 – ½	3.74	19.91	4.61	0.229	6.14	1.46	8.07	11.22
9223	2	½– 3½	3.73	19.70	4.68	.218	6.41	1.48	7.97	11.08
9224	3	3½–14	3.62	19.21	4.40	.232	5.59	1.53	7.37	10.74
9225	4	14 –21	3.58	19.44	4.38	.226	6.06	1.53	7.80	10.74
9226	5	21 –33	3.71	20.44	4.63	.222	5.61	1.41	7.55	11.57
9227	6	33 –40	3.60	21.62	4.46	.207	5.63	1.44	6.61	11.41
9228	7	40 –48	3.67	21.13	4.43	.210	5.66	1.49	6.73	11.05
9229	8	48 –72	3.61	20.32	4.40	.216	5.45	1.42	7.50	11.43
9230	9	72 –96	3.72	21.02	4.52	.215	5.77	1.55	8.50	11.57

[1] Carbonates deducted.
[2] Combined water plus water equivalent of the bases.
[3] Combined water plus water equivalent of bases, corrected for organic-matter and carbonate content.

HAYS SILTY CLAY LOAM

The data on this profile are taken for the most part from Technical Bulletin 316 (*31*). In this bulletin it is described under the name of Colby silty clay loam. It lies close to the western border of the Chernozem belt of soils. It is included in the present series because of the intermediate position it occupies between the northerly and southerly members.

The mechanical analyses (table 21) indicate a soil fairly permeable to water. The coarse material in the surface horizon as well as the increased content of clay at lower levels indicate some illuviation and the general information in Technical Bulletin 316 (*31*) indicates surface removal of fine material by wind and water erosion.

TABLE 21.—*Mechanical analyses of Hays silty clay loam* [1]

Sample no.	Horizon	Depth	Fine gravel (2–1 mm)	Coarse sand (1–0.5 mm)	Medium sand (0.5–0.25 mm)	Fine sand (0.25–0.1 mm)	Very fine sand (0.1–0.05 mm)	Silt (0.05–0.005 mm)	Clay (0.005–0 mm)	Colloid (0.002–0 mm)
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6842	1	2–10	0.2	1.0	1.4	2.9	12.6	45.2	34.0	30.2
6843	2	10–20	.3	.8	1.4	2.9	18.2	42.3	38.0	32.4
6844	3	20–33	.2	.3	.5	1.9	11.0	47.0	38.7	30.3
6845	4	33–47	.1	.4	.8	.2	10.5	47.7	38.2	28.6
6846	5	47–60	.1	.2	.6	1.5	8.3	50.8	38.3	29.0
6847	6	60–72	.1	.5	1.8	4.2	11.4	46.1	35.7	26.8

[1] Data from Technical Bulletin 316 (*31, p. 10*), Colby silty clay loam. Organic matter not determined.

The chemical analyses (table 22) indicate considerable surface leaching through the high percentage of silica in the surface horizon but no marked evidence of colloid accumulation at lower levels. The calcium oxide and carbon dioxide percentages indicate calcium carbonate present throughout the profile with no sharply marked zone of carbonate accumulation. The pH values are those normal for soils containing calcium carbonate. The soluble salts vary but slightly throughout. The organic matter in quantity and distribution is in no way abnormal for soils of the type.

TABLE 22.—*Chemical analyses of Hays silty clay loam soil* [1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6842	1	2–10	68.50	3.52	11.70	1.11	4.30	2.58	0.98	0.62
6843	2	10–20	62.92	2.40	11.55	1.09	8.22	2.27	.90	.53
6844	3	20–33	59.78	2.64	11.00	1.17	10.54	1.87	1.02	.49
6845	4	33–47	59.30	2.64	11.35	1.19	11.08	2.23	1.08	.53
6846	5	47–60	61.50	3.04	12.35	1.25	10.00	2.27	1.17	.53
6847	6	60–72	61.20	3.52	10.06	1.15	10.80	2.38	.87	.53

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [2]	CO_2 [3]	N	pH	Soluble salts [4]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
6842	0.07	0.16	0.14	6.49	100.17	2.82	2.98	0.15	8.3	1,180
6843	.06	.15	.14	9.63	99.86	1.11	6.07	.07	8.4	940
6844	.06	.14	.14	10.75	99.58	.65	7.55	.04	8.5	920
6845	.05	.19	.14	10.30	100.09	.32	8.27	.03	8.5	900
6846	.06	.18	.15	8.60	101.07	.13	7.32	.03	8.5	960
6847	.06	.17	.14	9.53	100.41	.14	7.90	.03	8.5	1,000

[1] Data from Technical Bulletin 316 (*31, pp. 10 and 30*), Colby silty clay loam except soluble salts.
[2] By combustion method ($CO_2 \times 0.471$). [3] CO_2 of the carbonates. [4] Determined by the bridge method.

The colloid analyses (table 23) show the usual relations of the soils of the semiarid area. The distribution of the carbonates throughout the profile in the soil repeats itself in the colloid, except that the zone of carbonate concentration is not defined in the dispersed material. The usual excess of silica content of the surface layer over that of the horizons immediately beneath is present, though it is very small.

TABLE 23.—*Chemical analyses of Hays silty clay loam colloid* [1]

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6842	1	2–10	42	49.31	7.10	19.67	2.71	4.35	2.30
6843	2	10–20	52	46.95	6.76	19.03	2.77	7.68	2.09
6844	3	20–33	55	48.60	6.96	19.23	3.07	7.26	2.11
6845	4	33–47	57	48.00	6.28	19.09	3.14	8.83	2.10
6846	5	47–60	52	49.00	6.72	19.00	3.21	7.40	2.03
6847	6	60–72	43	47.20	6.55	18.31	3.15	10.23	2.11

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [2]	CO_2 [3]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6842	0.28	0.52	0.11	0.15	0.14	13.41	100.05	4.07	1.85	0.30
6843	.17	.50	.11	.14	.13	13.09	100.02	1.79	3.74	.17
6844	.20	.49	.12	.14	.11	12.03	100.38	.62	3.85	.09
6845	.37	.50	.11	.14	.09	12.12	100.77	.53	4.65	.09
6846	.23	.48	.11	.14	.09	11.57	99.98	.23	4.23	.06
6847	.24	.46	.10	.13	.10	12.25	100.83	.21	5.11	.05

[1] Data taken from Technical Bulletin 316 (*31, pp. 27–28*), Colby silty clay loam.
[2] Determined by combustion method ($CO_2 \times 0.471$). [3] CO_2 of the carbonates.

The essential uniformity of the inorganic colloid is still more sharply defined by the derived data (table 24). The uniformity of the formula-weight ratios, especially to a depth of 33 inches, is so striking as to make it evident that this inorganic colloid is constant in composition. The slight excess of bases in the horizon may be safely attributed to the presence of undecomposed, or partially unhydrolyzed material.

TABLE 24.—*Derived data: Hays silty clay loam colloid*

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid [3]
			$\frac{SiO_2}{Fe_2O_3 \cdot Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$ [1]	$\frac{SiO_2}{H_2O}$ [2]		
		Inches							*Percent*	*Percent*
6842	1	2–10	3.45	18.50	4.25	0.230	6.20	1.49	7.40	10.65
6843	2	10–20	3.41	18.47	4.18	.227	5.37	1.30	8.16	12.02
6844	3	20–33	3.47	18.55	4.29	.231	5.58	1.43	7.60	11.23
6845	4	33–47	3.52	20.32	4.27	.210	5.06	1.46	6.94	11.00
6846	5	47–60	3.57	19.39	4.38	.226	5.83	1.52	7.11	10.67
6847	6	60–72	3.56	19.17	4.37	.228	4.63	1.41	6.93	11.32

[1] Carbonates deducted.
[2] Combined water plus water equivalent of the bases.
[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.

PULLMAN SILTY CLAY LOAM

The data on the Pullman silty clay loam profile here discussed are taken, with some additions, from Technical Bulletin 228 (*3*, *p. 3*). It is there described as a southern Chernozem. It is included here to complete a series of soils developed under deficient rainfall and increasing mean annual temperature. This soil is of particular interest since it is developed from outwash material at successive stages and shows the presence of a buried soil. It appears that the colloid composition is markedly affected by the parent material.

The mechanical analyses (table 25) show the presence of less than 20 percent material coarser than silt. The soil may therefore be considered only moderately permeable by water. There is fairly distinct evidence of colloid accumulation in the second and third horizons. The evidence of removal of colloid by wind or water erosion from the surface is still more marked.

TABLE 25.—*Mechanical analyses of Pullman silty clay loam* [1]

Sample no.	Horizon	Depth	Fine gravel (2–1 mm)	Coarse sand (1–0.5 mm)	Medium sand (0.5–0.25 mm)	Fine sand (0.25–0.1 mm)	Very fine sand (0.1–0.05 mm)	Silt (0.05–0.005 mm)	Clay (0.005–0 mm)	Colloid (0.002–0 mm)	Organic matter by H_2O_2 [2]
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
4574	1	0– 5	0.0	0.2	0.3	2.6	12.1	55.1	27.6	23.9	2.0
4575	2	10– 20	0	.1	.2	1.9	8.3	41.0	47.4	42.8	1.1
4576	3	30– 40	1.0	.5	.4	1.6	6.9	45.2	43.8	37.6	.5
4577	4	54– 64	.1	.3	.4	3.4	16.6	41.2	37.9	34.6	.3
4578	5	70– 75	.1	.4	.4	2.2	9.2	34.1	53.4	35.9	.3
4579	6	90–100	.2	.2	.3	2.1	12.2	41.0	44.0	31.3	0

[1] Data from Technical Bulletin 228 (*3*, *p. 5*), Amarillo silty clay loam.
[2] Also includes solution loss of inorganic matter.

The variations shown by the chemical analyses of the soil (table 26) are quite marked. They are due in part to the high silt content of the surface soil, in part to the variation in colloid content of the different horizons, but are chiefly owing to the high carbonate content of the fifth and sixth horizons. The leaching of the first horizon is indicated by the high silica content, the absence of carbonates, and the low pH value. It would appear that the buried soil had reached a greater degree of maturity than the present surface soil or that its parent material has a different composition. At any rate, the first four horizons carry a considerable quantity of undecomposed feldspars. There is distinct accumulation of carbonate in both the modern and buried soil.

TABLE 26.—*Chemical analyses of Pullman silty clay loam*[1]

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
4574	1	0- 5	75.62	3.16	10.56	0.78	0.67	2.20	1.06	0.78
4575	2	10- 20	70.48	4.40	13.86	1.35	.97	2.56	1.01	.71
4576	3	30- 40	68.72	4.31	13.25	1.37	2.64	2.48	1.03	.74
4577	4	54- 64	74.49	3.83	11.67	1.10	1.09	2.14	.87	.95
4578	5	70- 75	40.42	2.04	6.69	1.06	25.80	1.20	.46	.42
4579	6	96-100	56.71	2.86	[2] 9.26	1.22	14.11	1.71	.73	.57

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[3]	CO_2[4]	N	pH	Soluble salts[5]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
4574	0.09	0.10	0.07	4.98	100.07	3.13	0.00	0.13	6.5	480
4575	.09	.09	.07	4.94	100.55	1.39	.00	.08	7.8	2,200
4576	.08	.10	.06	5.50	100.28	1.15	1.32	.06	7.8	2,720
4577	.06	.07	.21	3.82	100.30	.54	.06	.02	7.9	2,520
4578	.04	.06	.13	21.62	100.16	.20	19.60	.01	7.9	3,440
4579	.06	.09	.11	13.00	100.43	-------	10.43	.01	-------	-------

[1] Data from Technical Bulletin 228 (*5, p. 6*), Amarillo silty clay loam, except for additions of CO_2 of the carbonates, organic matter, soluble salts, and totals.
[2] This figure corrects that of Technical Bulletin 228, which was in error.
[3] Determined by combustion method ($CO_2 \times 0.471$).
[4] CO_2 of the carbonates.
[5] Determined by the bridge method.

In contrast with the soil data, the colloid data (table 27) show very slight variation in composition for the first four horizons. The variations shown by the fifth and sixth horizons are owing chiefly to the presence of dispersed carbonates. The carbonate content of the fifth horizon is exceptionally great.

TABLE 27.—*Chemical analyses of Pullman silty clay loam colloid* [1]

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
4574	1	0- 5	70	50.51	8.80	22.04	2.08	1.48	2.08
4575	2	10- 20	25	51.51	8.01	22.71	2.68	1.59	2.54
4576	3	30- 40	37	51.32	8.46	22.43	2.80	2.27	2.50
4577	4	54- 64	29	51.23	8.19	24.08	2.83	1.73	2.42
4578	5	70- 75	29	38.42	6.71	17.64	2.53	16.38	1.83
4579	6	96-100	47	45.88	6.89	20.09	2.87	9.05	2.26

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [2]	CO_2 [3]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
4574	0.06	0.56	0.14	0.20	0.18	12.08	100.81	4.02	0.00
4575	.01	.57	.09	.12	.14	9.50	100.05	2.14	.00
4576	.00	.58	.05	.14	.14	10.19	100.94	1.90	.35
4577	.10	.55	.07	.11	.13	8.72	100.10	.96	.00
4578	.06	.37	.06	.09	.10	17.85	101.04	.42	11.22
4579	.01	.52	.05	.11	.13	12.41	100.27	.13	5.87

[1] Data from Technical Bulletin 228 (*5, p. 10*), Amarillo silty clay loam, except totals.

[2] By combustion method ($CO_2 \times 0.471$).

[3] CO_2 of the carbonates.

The derived data (table 28) still more fully emphasize the essentially constant composition of the inorganic colloid of the first three layers of soil. Indeed the whole profile shows no marked variations. There are some minor distinctions such as the change in the iron oxide-alumina ratio which probably marks the top portion of the residual buried soil. The higher values of the silica-total base ratio and of the percentage of combined water probably reflect in part the leaching of the surface soil which accompanied the colloid removal previously mentioned. In general, in this, as in other semiarid soils, the colloid movements have not been marked by extensive change in the colloid composition. The color of the organic free soil and colloid indicated that a part at least of the iron present exists as the free oxide.

TABLE 28.—*Derived data: Pullman silty clay loam colloid*

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid [3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}^1}$	$\frac{SiO_2}{H_2O^2}$		
		Inches							*Percent*	*Percent*
4574	1	0- 5	3.10	15.25	3.89	0.255	7.80	1.51	8.06	10.43
4575	2	10- 20	3.09	15.89	3.84	.242	7.05	1.61	7.30	9.86
4576	3	30- 40	3.13	16.11	3.87	.241	6.60	1.51	7.88	10.50
4577	4	54- 64	2.97	16.65	3.61	.217	6.04	1.52	7.76	10.17
4578	5	70- 75	3.06	17.91	3.70	.206	5.32	1.37	6.21	11.30
4579	6	96-100	3.18	15.37	3.37	.219	6.21	1.59	6.41	9.98

[1] Carbonates deducted.

[2] Combined water plus water equivalent of the bases.

[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.

PECOS SANDY LOAM

Two profiles of Pecos sandy loam soil were collected by C. W. Botkin of the New Mexico Agricultural College and sent to the Bureau of Chemistry and Soils for mechanical analyses and for the separation of colloids. Permission was given to use these profiles in the present study. The profiles were selected to compare the irrigated and unirrigated soils in the Pecos Valley. The two profiles were chosen, with the aid of W. G. Harper of the Soil Survey Division, to be as nearly identical before irrigation was begun in 1896, so far as could be ascertained at the time of collection. The samples were collected in 1933. In order to facilitate comparison the separate portions of analytical data for the virgin and irrigated soils will be placed in immediate sequence. It will be noted that the two profiles are of different depth and subdivision. These differences are due to field differences as determined by the collectors.

The mechanical analyses of the two profiles (table 29) show not only very marked textural uniformity but the degree to which the collectors succeeded in securing profiles of like kind. Both profiles show a small increase of coarser material with increase in depth. Both show somewhat increased clay and colloid content below the surface horizon. Both show a sufficient quantity of sands to insure reasonable permeability to water. There is not sufficient difference to warrant any positive statement concerning any effect produced by the years of irrigation and crop production on the soil texture.

TABLE 29.—*Mechanical analyses of Pecos sandy loam* [1]

VIRGIN SOIL

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-722	1	0- 9	0.1	0.3	0.6	4.9	30.9	27.3	29.1	22.2	0.4
B-723	2	9-18	.1	.2	.4	4.5	32.8	28.7	32.5	25.0	.3
B-724	3	18-34	.1	.2	.5	3.3	30.1	30.6	34.0	28.8	[2]0
B-725	4	34-48	0	.2	.5	2.7	25.0	28.4	42.7	32.3	.1
B-726	5	48-71	.1	.5	.8	3.2	24.9	33.8	36.1	28.4	.2
B-727	6	71-83	.3	2.0	3.6	7.5	27.3	32.8	20.2	18.6	[2]0
B-728	7	83-95	.1	1.1	2.8	8.7	29.9	34.5	22.7	16.6	[2]0

IRRIGATED SOIL

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
B-713	1	0- 9	0.2	0.5	0.9	5.1	37.5	28.2	25.9	18.9	0.5
B-714	2	9- 18	.1	.4	.5	3.9	31.2	32.4	30.3	22.2	.4
B-715	3	18- 35	.1	.3	.5	3.3	31.7	31.9	31.2	26.6	.5
B-716	4	35- 47	0	.3	.7	5.3	36.4	24.1	31.9	25.0	.4
B-717	5	47- 53	.1	.4	.7	4.6	35.1	22.3	35.7	26.9	.7
B-718	6	53- 64	.1	.4	.9	5.2	32.2	22.2	37.9	27.8	.3
B-719	7	64- 82	.1	.6	1.4	5.8	32.1	23.9	35.3	24.4	.1
B-720	8	82- 90	.2	.9	1.9	5.8	35.3	26.3	26.9	20.6	.1
B-721	9	90-101	.2	1.5	3.1	8.8	36.6	26.0	23.2	18.0	[2]0

[1] Determinations by H. W. Lakin and T. M. Shaw.
[2] Organic matter not present in excess of 0.4 percent.

The chemical analyses of the soil (table 30) of the profiles show general uniformity of composition with minor differences within each profile and between the virgin and irrigated soils. The silica content of the surface horizon in both profiles reflects the high silt and sand content shown in the mechanical anaylses. The very high magnesium oxide content especially of the lower layers of both profiles probably reflects, as does the color of the soil, the influence of the parent material derived from the "Red Beds." Part of the magnesia must be considered as associated with the calcium carbonate. The carbonates present are partly dolomitic. In both samples carbonates are present throughout the profiles and in both increase with depth.

There is no evidence of accumulation at any definite point. Removal of carbonates from the upper portions of both profiles is indicated in this permeable material. It will be observed that the years of crop production have not increased the organic content of the surface soil but apparently irrigation has carried organic matter in slightly increased amounts to somewhat lower levels. The most sharply defined differences between the virgin and irrigated soils shown in these analyses are in the pH values and soluble salt content. In the nonirrigated soil an indefinite zone of salt accumulation appears to exist but is so slight as to be perhaps only seasonal; the pH values are higher than correspond to soils containing only calcium carbonate. The increased salt content of the irrigated soil is doubtless owing to the salt content of the irrigation water which contains sodium chloride and calcium sulphate (*15*).

TABLE 30.—*Chemical analyses of Pecos sandy loam*[1]

VIRGIN SOIL

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-722	1	0- 9	64.73	2.62	8.47	2.41	8.48	1.99	0.68	0.44
B-723	2	9-18	61.99	2.36	8.46	2.50	9.63	1.96	.62	.45
B-724	[2] 3	18-34	60.01	2.58	8.58	2.58	10.05	2.00	.46	.51
B-725	4	34-48	53.40	2.50	8.30	2.78	14.88	1.79	.41	.46
B-726	5	48-71	50.22	2.28	8.13	4.45	15.23	1.70	.47	.47
B-727	6	71-83	48.28	2.05	0.97	6.01	15.28	1.52	.49	.45
B-728	7	83-95	50.00	1.97	6.62	6.20	14.67	1.51	.50	.41

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[3]	CO_2[4]	N	pH	Soluble salts[5]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*P. p. m.*
B-722	0.07	0.01	0.08	10.42	100.38	1.14	7.42	0.06	8.6	820
B-723	.06	.02	.03	11.63	99.79	.69	8.50	.05	8.5	880
B-724	.06	.07	.06	12.12	99.68	.89	9.38	.04	8.6	1,000
B-725	.05	.08	.06	15.40	100.11	.43	12.81	.03	8.4	1,040
B-726	.05	.06	.05	17.12	100.23	.38	14.98	.02	8.8	1,000
B-727	.05	.04	.07	18.85	100.06	.40	16.60	.01	8.8	940
B-728	.06	.05	.06	18.22	100.17	.30	16.22	.01	8.8	920

IRRIGATED SOIL

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-713	1	0- 9	66.39	2.48	8.26	2.20	7.77	1.97	0.65	0.56
B-714	2	9- 18	62.27	2.54	8.61	2.52	9.55	1.94	.62	.56
B-715	3	18- 35	62.51	2.67	8.75	2.30	9.48	1.93	.60	.53
B-716	4	35- 47	64.78	2.38	8.13	1.76	9.61	1.87	.72	.50
B-717	5	47- 63	61.22	2.24	7.77	1.66	12.62	1.72	.58	.45
B-718	6	63- 64	52.79	1.88	6.30	2.44	17.40	1.49	.59	.40
B-719	7	64- 82	50.49	1.67	6.41	3.34	17.73	1.38	.53	.37
B-720	8	82- 90	52.18	1.77	6.28	4.40	15.50	1.51	.59	.38
B-721	9	90-101	52.20	1.79	6.24	5.00	15.08	1.40	.70	.37

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[3]	CO_2[4]	N	pH	Soluble salts[5]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*P. p. m.*
B-713	0.06	0.00	0.18	9.87	100.57	1.25	6.78	0.07	8.2	3,000
B-714	.06	.00	.30	10.83	99.80	.60	8.55	.05	8.1	3,300
B-715	.06	.08	.34	10.81	100.02	.57	8.20	.03	8.0	3,100
B-716	.05	.10	.30	10.10	100.30	.50	7.90	.03	8.1	3,980
B-717	.05	.07	.28	11.72	100.48	.53	10.28	.03	8.1	3,940
B-718	.06	.02	.22	16.43	100.02	.34	14.78	.02	8.2	3,020
B-719	.04	.01	.21	17.83	100.01	.48	16.21	.02	8.2	3,400
B-720	.04	.02	.11	17.12	100.20	.20	15.77	.01	8.1	2,620
B-721	.04	.02	.14	17.25	100.23	.34	15.48	.01	8.2	2,350

[1] Determinations by O. Edgington, except pH and soluble salts and selenium.

[2] Selenium determined by K. T. Williams, 0.15 p. p. m.

[3] By combustion method ($CO_2 \times 0.471$).

[4] CO_2 of the carbonates.

[5] By bridge method.

The colloid analyses (table 31) emphasize the uniformity of the colloidal material in both profiles as well as in each profile despite certain definite differences. The high content of iron oxide of the colloidal material as compared with the soil analyses indicates that essentially all iron oxide present is colloidal. Both profiles show distinct evidence of colloidal carbonate accumulation and this is at a somewhat lower level in the irrigated profile. There is no evidence of dolomitic carbonate in the colloid. The concentration of carbonate in the lower portion of the irrigated profile is materially greater than in the virgin profile. As is to be expected the sulphate differences which appear in the soil analyses disappear in the colloid analyses. The organic matter in the colloid is distributed to somewhat lower levels in the colloid of the irrigated soil and would appear to be more readily dispersed than in the virgin profile.

TABLE 31.—*Chemical analyses of Pecos sandy loam colloid*

VIRGIN SOIL

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-722	1	0- 9	32	42.76	6.11	18.13	3.83	9.62	2.77
B-723	2	9-18	54	43.60	6.48	18.31	3.71	8.84	2.58
B-724	3	18-34	48	43.60	6.28	18.18	3.86	8.93	2.38
B-725	4	34-48	50	39.90	5.55	16.71	3.94	12.81	1.94
B-726	5	48-71	46	43.50	5.95	18.22	4.58	9.06	1.89
B-727	6	71-83	51	44.92	6.13	18.15	5.02	7.80	2.07
B-728	7	83-95	53	47.70	6.44	19.25	5.60	5.12	1.71

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[1]	CO_2[2]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-722	0.02	0.48	0.10	0.18	0.18	16.14	100.32	1.56	6.86	0.12
B-723	.33	.44	.08	.33	.10	15.25	100.05	1.68	6.02	.13
B-724	.21	.43	.07	.21	.12	15.32	99.59	1.06	6.43	.09
B-725	.17	.41	.05	.18	.11	17.85	99.62	.89	9.25	.08
B-726	.19	.48	.06	.13	.09	15.47	99.62	.41	6.80	.07
B-727	.13	.41	.07	.20	.08	14.64	99.62	.48	5.82	.07
B-728	.25	.45	.08	.28	.09	12.74	99.81	.82	3.61	.07

IRRIGATED SOIL

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-713	1	0- 9	44	44.08	6.45	18.96	3.83	8.42	2.34
B-714	2	9- 18	47	44.40	6.48	18.88	3.75	8.43	2.48
B-715	3	18- 35	41	45.39	6.74	19.73	3.85	7.25	2.48
B-716	4	35- 47	41	42.62	5.99	18.02	3.47	10.54	2.25
B-717	5	47- 53	51	37.00	5.49	16.09	3.29	15.06	2.06
B-718	6	53- 64	37	34.15	4.49	14.81	3.11	19.04	1.71
B-719	7	64- 82	41	36.70	4.85	16.05	3.71	16.21	1.75
B-720	8	82- 90	36	38.17	5.13	16.33	4.29	14.77	1.77
B-731	9	90-101	46	42.11	5.56	17.65	4.79	10.88	1.92

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[1]	CO_2[2]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-713	0.26	0.58	0.12	0.26	0.11	14.85	99.61	2.19	5.37	0.13
B-714	.13	.50	.10	.24	.07	14.39	99.88	1.77	5.36	.10
B-715	.12	.52	.10	.20	.07	13.47	99.95	1.62	4.63	.12
B-716	.07	.52	.08	.21	.07	16.10	99.94	1.24	7.42	.12
B-717	.33	.46	.09	.10	.09	19.30	100.21	1.36	10.48	.09
B-718	.13	.42	.06	.18	.14	21.70	100.03	.86	14.10	.08
B-719	.13	.42	.07	.09	.14	19.07	99.69	.53	12.37	.08
B-720	.11	.38	.07	.08	.08	19.04	100.22	.91	11.05	.10
B-721	.13	.42	.09	.09	.11	16.03	100.28	.80	7.94	.07

[1] Determined by combustion method (CO_2×0.471).

[2] CO_2 of the carbonates.

The derived data (table 32) emphasize the essential constancy of composition of the inorganic colloid. There are minor variations in both profiles. In the irrigated profile the silica-total base ratio is sensibly lower than in the virgin profile as a consequence of bases derived from the irrigation waters by base exchange. The apparently greater combined water content of the lower portion of the virgin profile is due to the greater carbonate content of the lower portion of the irrigated profile (table 31). These differences disappear almost wholly in the combined water of the soil acid.

TABLE 32.—*Derived data: Pecos sandy loam colloids*

VIRGIN SOIL

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid [3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$ [1]	$\frac{SiO_2}{H_2O}$ [2]		
		Inches							*Percent*	*Percent*
B-722	1	0- 9	3.20	20.39	3.99	0.216	5.05	1.25	7.72	12.36
B-723	2	9-18	3.29	17.81	4.04	.227	4.97	1.26	7.75	12.25
B-724	3	18-34	3.33	18.41	4.06	.221	5.23	1.26	7.83	12.22
B-725	4	34-48	3.34	19.08	4.05	.212	4.77	1.17	7.68	13.05
B-726	5	48-71	3.35	19.40	4.05	.209	5.01	1.20	8.26	12.90
B-727	6	71-83	3.45	19.30	4.20	.216	4.79	1.20	8.34	12.90
B-728	7	83-95	3.44	19.59	4.18	.213	4.61	1.25	8.31	12.53

IRRIGATED SOIL

Sample no.	Horizon	Depth	$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$ [1]	$\frac{SiO_2}{H_2O}$ [2]	Combined water	Combined water of the soil acid [3]
B-713	1	0- 9	3.32	18.10	4.06	0.225	4.80	1.31	7.29	11.71
B-714	2	9- 18	3.26	18.13	3.98	.220	4.81	1.32	7.26	11.65
B-715	3	18- 35	3.20	17.83	3.90	.218	5.09	1.36	7.32	11.36
B-716	4	35- 47	3.31	18.60	4.01	.213	5.32	1.29	7.44	12.02
B-717	5	47- 53	3.28	18.28	3.99	.218	4.63	1.13	7.52	13.33
B-718	6	53- 64	3.27	20.17	3.90	.194	4.86	1.15	6.83	13.31
B-719	7	64- 82	3.32	20.02	3.97	.198	5.02	1.19	7.07	12.95
B-720	8	82- 90	3.30	19.75	3.96	.201	4.51	1.19	7.08	13.00
B-721	9	90-101	3.37	20.10	4.05	.202	4.54	1.18	7.59	12.70

[1] Carbonates deducted.
[2] Combined water plus water equivalent of the bases.
[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.

PIMA CLAY ADOBE

The two profiles of Pima clay adobe were, like the Pecos profiles, sent by C. W. Botkin. They were selected to present, as nearly as possible, like conditions before irrigation was begun in 1894. The data are placed, therefore, in sequence. It will be seen from the texture shown in table 33 that the selection was excellent as respects the upper portion of the two profiles but the comparison becomes less satisfactory with depth. Probably this was unavoidable because of the great heterogeneity of the alluvial deposits in the flood plain of the Rio Grande.

TABLE 33.—*Mechanical analyses of Pima clay adobe*[1]

VIRGIN SOIL

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-706	1	0-9	0.5	0.4	0.6	1.4	2.1	19.5	74.4	59.2	0.4
B-707	2	9-29	.1	.3	.6	2.2	3.5	23.8	68.6	51.4	[2]0
B-708	3	29-41	.1	.3	.5	1.3	1.8	45.9	49.2	34.1	[2]0
B-709	4	41-45	.8	2.5	9.2	18.3	6.3	10.4	52.1	43.2	.1
B-710	5	45-49	.7	5.1	20.3	33.9	11.3	9.1	13.2	12.1	.1
B-711	6	49-54	1.3	6.5	28.0	49.6	7.4	2.6	4.3	3.8	[2]0
B-712	7	54-84	1.9	12.0	30.7	49.9	3.0	.3	1.1	1.0	[2]0

IRRIGATED SOIL

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
B-700	1	0-9	0.3	1.2	2.4	5.6	5.8	15.2	68.0	54.7	0.9
B-701	2	9-21	.1	.2	.5	1.4	2.6	20.9	73.6	56.7	.1
B-702	3	21-48	.1	.3	.6	2.1	8.2	45.2	42.9	32.5	[2]0
B-703	4	48-51	.1	.6	2.2	5.2	3.2	35.1	52.8	37.9	.2
B-704	5	51-58	.1	2.3	11.2	35.7	19.7	9.4	21.1	18.4	[2]0
B-705	6	58-89	0	2.1	21.1	61.3	10.5	1.9	2.9	2.9	[2]0

[1] Determinations by H. W. Lakin and T. M. Shaw.
[2] Organic matter not present in excess of 0.4 percent.

The clay and silt content of the upper two horizons is so high in both profiles as to present the picture of a nearly impermeable soil. The abrupt textural change in the lower part of the profiles points to a different parent material, but this difference is probably textural since the sources of the parent material are presumably the same and the differences are due to the character of deposits made at different flood periods. The permeability of the lower portions is a contributing factor to the successful use of underdrainage in this irrigation project. The larger quantities of coarse material in the first horizon of both profiles as compared with the second may be taken to be due to removal of surface soil fine material, only a portion of which finds lodgment at lower levels. The increased organic content of the upper horizon of the irrigated profile may be ascribed in part at least to the preservative qualities of the heavy clay in contrast with the more sandy Pecos profiles. The effect of percolating irrigation water on colloidal distribution would appear to be limited to the first two horizons.

The chemical analyses of the two profiles (table 34) indicate that horizon 4 is a transitional layer between the upper and lower portions of the profile. The evidence of two separate deposits appears in the distribution of the iron oxide, magnesia, sodium oxide, and carbonates. There is no definite evidence of dolomitic carbonate despite the rather close correlation between the quantities of magnesia and of carbon dioxide. The small concentration of carbonates in the third horizon of the virgin soil indicated by the carbon dioxide percentages is at a slightly lower level in the irrigated profile. The variation of coarse materials in both profiles obscures any inferences to be drawn from variation in the minor constituents. Evidence of the probable influence of irrigation water in removal of fine material from the surface horizon is seen in the greater divergence in composition of the first and second horizons of the irrigated soil as compared with the corresponding horizons of the virgin profile. The highly impermeable character of the surface soil is indicated by the accumulation of soluble salts in the second, third, and fourth layers of the virgin soil and the practical absence of such accumulation of salts in the irrigated profile despite the presence of soluble salts in the irrigation water (*27*). It seems probable that the drainage system in the irrigated area is responsible for the lower pH values of the deeper strata of the irrigated profile as compared with the virgin profile.

TABLE 34.—*Chemical analyses of Pima clay adobe soil* [1]

VIRGIN SOIL

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-706	1	0–9	55.07	5.35	16.60	2.52	5.38	2.47	0.74	0.66
B-707 [2]	2	9–29	56.63	5.08	15.95	2.64	5.55	2.08	1.12	.63
B-708	3	29–41	58.65	4.64	14.82	2.22	6.10	2.38	1.27	.75
B-709	4	41–45	66.39	4.31	14.32	1.89	3.00	2.49	1.08	.56
B-710	5	45–49	79.79	2.34	9.26	.65	1.80	2.18	1.40	.45
B-711	6	49–54	82.90	1.69	8.25	.39	1.29	2.17	1.57	.31
B-712	7	54–84	83.50	1.50	8.37	.10	1.26	2.18	1.61	.28

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [3]	CO_2 [4]	N	pH	Soluble salts [5]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
B-706	0.12	0.19	0.03	10.37	100.10	1.13	3.18	0.12	8.2	1,720
B-707 [2]	.14	.24	.30	9.53	100.49	1.12	3.31	.08	8.1	6,040
B-708	.10	.16	.29	8.48	99.86	.49	3.74	.05	8.0	4,500
B-709	.10	.11	.08	5.90	100.32	.52	1.29	.04	8.0	3,680
B-710	.05	.06	.04	1.85	99.87	.09	.73	.02	8.4	1,200
B-711	.04	.05	.01	1.18	99.85	0	.29	.01	8.8	560
B-712	.03	.04	.05	.63	99.55	0	.27	.006	9.2	340

IRRIGATED SOIL

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-700	1	0–9	58.99	4.89	16.15	1.65	4.32	2.03	0.80	0.68
B-701	2	9–21	56.72	5.30	16.60	2.60	5.09	2.66	.92	.70
B-702	3	21–48	62.00	4.15	13.55	1.98	6.01	2.60	1.26	.63
B-703	4	48–51	60.01	4.52	14.34	2.04	6.20	2.40	1.14	.65
B-704	5	51–58	74.47	2.72	10.78	.102	2.82	2.26	1.33	.44
B-705	6	58–89	83.21	.94	8.72	.36	1.47	2.33	1.67	.28

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [3]	CO_2 [4]	N	pH	Soluble salts [5]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
B-700	0.09	0.20	0.13	9.41	100.94	1.82	2.34	0.11	8.1	1,480
B-701	.13	.17	.15	9.30	100.49	1.24	2.89	.09	8.0	1,700
B-702	.10	.18	.14	7.86	100.48	0	3.58	.05	8.1	1,620
B-703	.10	.12	.13	8.39	100.04	.15	3.86	.05	8.1	1,940
B-704	.06	.06	.11	3.58	99.65	0	1.53	.02	8.2	1,960
B-705	.03	.06	.11	1.07	100.25	0	.54	.01	8.6	700

[1] Determinations by Glen Edgington except pH and soluble salts and selenium.
[2] Determination of 0.15 p. p. m. of selenium by K. T. Williams.
[3] By combustion method ($CO_2 \times 0.471$).
[4] CO_2 of the carbonates.
[5] By bridge method.

Since this soil is so high in colloid, is derived in part from shale, and has physical characteristics similar to those of the Pierre clay from South Dakota, it seemed of interest to ascertain if selenium were present. The amount found in the second horizon is only 0.15 p. p. m. and is no higher than is found in the Pecos profile. It seemed insufficient to warrant further determinations.

The colloids of the deepest portion of the profiles were not analyzed because of lack of material. The variations of composition shown by the tables of mechanical analyses and chemical analyses of the soil largely disappear in the colloid analyses (table 35). Not only is the colloid of each profile constant in composition within narrow limits but the colloid from the irrigated profile is almost as closely similar to the virgin profile as are duplicate analyses to each other. The only essential difference between the colloids is in the quantity and location of the carbonates as shown by the carbon dioxide and calcium oxide content. In both profiles the magnesium oxide and potassium oxide content are sufficiently high to indicate the possibility of undecomposed silicate minerals in the colloid.

TABLE 35.—*Chemical analyses of Pima clay adobe colloid*

VIRGIN SOIL

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-706 [1]	1	0-9	49	51.79	7.64	21.42	4.05	3.06	2.52
B-707 [1]	2	9-29	46	51.58	7.78	20.24	4.29	3.30	2.32
B-708 [2]	3	29-41	37	52.40	8.08	19.64	3.08	3.33	2.32
B-709 [2]	4	41-45	25	53.70	7.90	20.90	3.48	2.11	2.46
B-710 [2]	5	45-49	37	53.30	8.35	19.97	3.64	1.79	2.48
B-711 [2]	6	49-54	32	53.02	8.21	19.83	3.50	1.85	2.38

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [3]	CO_2 [4]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-706 [1]	Trace	0.55	0.08	0.21	0.06	8.91	100.29	1.45	0.95	0.11
B-707 [1]	0.07	.53	.12	.21	.07	9.39	99.99	1.46	1.31	.10
B-708 [2]	.32	.68	.08	.38	.09	9.52	100.52	1.43	1.13	.10
B-709 [2]	.25	.60	.07	.27	.05	8.76	100.73	1.01	.23	.10
B-710 [2]	.20	.65	.09	.23	.13	9.08	99.91	1.00	.14	.14
B-711 [2]	.27	.67	.07	.29	.11	9.50	99.76	2.17	.07	.15

IRRIGATED SOIL

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-700 [1]	1	0-9	38	51.65	7.66	22.38	3.61	2.62	2.65
B-701 [1]	2	9-21	38	52.06	7.88	21.23	3.96	2.80	2.57
B-702 [2]	3	21-48	31	51.00	7.86	10.01	3.74	4.28	2.04
B-703 [2]	4	48-51	37	52.48	7.98	20.07	3.57	3.17	2.38
B-704 [2]	5	51-58	36	53.50	8.19	20.12	3.57	2.39	2.57

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [3]	CO_2 [4]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-700 [1]	0.01	0.60	0.07	0.20	0.04	9.06	100.34	1.64	0.58	0.11
B-701 [1]	.12	.56	.08	.26	.07	8.96	100.55	1.40	.73	.10
B-702 [2]	.05	.65	.11	.42	.13	10.55	100.53	1.68	1.84	.12
B-703 [2]	.16	.61	.06	.19	.08	9.52	100.23	1.29	1.00	.11
B-704 [2]	.29	.67	.08	.32	.06	8.80	100.61	1.38	.31	.11

[1] Determinations by Glen Edgington except organic matter and CO_2.
[2] Determinations by I. C. Brown.
[3] Determined by the combustion method (CO_2×0.471).
[4] CO_2 of the carbonates.

The derived data (table 36) still further emphasize the constancy of the composition of the inorganic colloid. The degree of uniformity is the more striking because, as previously mentioned, it is probable that the profiles each represent two deposits of alluvial material. In both colloids the combined water and the combined water of the soil acids are slightly lower in the upper portion of the profiles.

TABLE 36.—*Derived data: Pima clay adobe colloids*

VIRGIN SOIL

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid[3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$[1]	$\frac{SiO_2}{H_2O}$[2]		
		Inches							*Percent*	*Percent*
B-706	1	0- 9	3.33	17.95	4.09	0.228	5.37	1.64	6.51	9.75
B-707	2	9-29	3.47	17.50	4.32	.246	5.25	1.61	6.62	9.89
B-708	3	29-41	3.58	17.16	4.52	.203	5.02	1.60	6.90	10.16
B-709	4	41-45	3.45	17.68	4.29	.243	5.91	1.55	7.52	10.36
B-710	5	45-49	3.65	17.30	4.54	.207	5.98	1.64	7.04	9.94
B-711	6	49-54	3.58	17.12	4.53	.205	5.90	1.58	7.34	10.26

IRRIGATED SOIL

Sample no.	Horizon	Depth	$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$[1]	$\frac{SiO_2}{H_2O}$[2]	Combined water	Combined water of the soil acid[3]
B-700	1	0- 9	3.24	18.05	3.95	0.219	5.83	1.62	6.84	9.80
B-701	2	9-21	3.36	17.52	4.16	.237	5.37	1.61	6.73	9.93
B-702	3	21-48	3.80	18.20	4.79	.203	5.74	1.64	7.03	10.45
B-703	4	48-51	3.53	17.44	4.43	.267	5.70	1.68	7.23	10.30
B-704	5	51-58	3.57	17.36	4.60	.260	5.08	1.60	7.17	10.20

[1] Carbonates deducted.
[2] Combined water plus water equivalent of the bases.
[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content

KELVIN SANDY LOAM AND KELVIN GRAVELLY LOAM

For some time the writers have been seeking soils developed in place and derived from trisilicate feldspars or from granite in which the feldspathic content is a trisilicate. It was hoped that in such case, were the leaching of limited amount, the colloid might approach montmorillonite in composition. The samples of Kelvin soils here reported were selected by W. G. Harper, of the Division of Soil Survey, as probably approaching as closely to the specifications as could be found. Unfortunately the feldspar in the parent material is chiefly disilicate, as shown by petrographic examination, and may therefore have in the colloid a maximum silica-alumina ratio of 4. Undoubtedly, also, a portion of the soil is of aeolian origin. The profiles are, however, of special interest because they present a Desert soil free from carbonates and with an extraordinarily low soluble salt content.

The mechanical analyses (table 37) of the sandy loam show a soil of moderate depth and with apparently almost no translocation of fine material. The organic matter of the soil is almost wholly confined to the surface inch. There appears to be some translocation of fine material in the gravelly loam but whether by removal from the surface soil by wind and water or by alluviation of the second horizon is not clear, although it is probably the latter.

TABLE 37.—*Mechanical analyses of Kelvin soils*[1]

KELVIN SANDY LOAM

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-5147	1	0- 1	12.8	16.6	7.4	8.6	7.5	22.3	22.3	18.0	2.0
B-5148	2	1- 8	12.0	19.6	8.8	10.1	8.5	18.5	22.1	20.0	[2]0
B-5149	3	8-20	18.1	27.5	10.2	10.5	7.1	16.2	9.6	7.7	[2]0
B-5150[3]	4	20+									

KELVIN GRAVELLY LOAM

Sample no.	Horizon	Depth	Fine gravel (2-1 mm)	Coarse sand (1-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.1 mm)	Very fine sand (0.1-0.05 mm)	Silt (0.05-0.005 mm)	Clay (0.005-0 mm)	Colloid (0.002-0 mm)	Organic matter by H_2O_2
B-5151	1	0-4	22.9	17.0	7.4	9.3	10.1	21.8	10.6	8.1	0.4
B-5152	2	4-8	22.0	15.6	6.9	9.2	10.2	20.9	14.7	12.9	.5
B-5153[3]	3	8+									

[1] Determinations by H. W. Lakin and T. M. Shaw.
[2] Organic matter not in excess of 0.4 percent.
[3] Sample mostly decayed rock, not analyzed.

The chemical analyses of the soils (table 38) and of the partly disintegrated parent granites show a marked difference between the profiles and also between the granites. The deeper profile has a much greater content of calcium, iron, and magnesium oxides than does the gravelly loam. These differences and variations in minor components indicate that the parent materials are essentially different. The sandy loam parent feldspar consists largely of calcium sodium silicates while the gravelly loam feldspar is chiefly potassium sodium trisilicate. It is known that feldspars containing calcium hydrolyze much more rapidly than other sorts. It is possible, therefore, that the greater depth as well as the finer texture of the sandy loam is owing in part to this difference in the character of the parent rock. The pH values in both profiles indicate removal of soluble salts resulting from mineral hydrolysis.

TABLE 38.—*Chemical analyses of Kelvin soils*[1]

KELVIN SANDY LOAM

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-5147	1	0- 1	61.58	5.26	16.75	1.41	3.02	2.61	2.59	0.65
B-5148	2	1- 8	63.40	4.65	17.58	1.09	3.24	2.33	2.39	.63
B-5149	3	8-20	63.64	4.54	17.69	1.12	3.98	2.22	2.90	.58
B-5150	4	20+	65.70	3.93	17.30	1.12	3.66	2.44	3.07	.52

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[2]	CO_2[3]	N	pH	Soluble salts
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
B-5147	0.15	0.20	0.08	5.81	100.11	2.62	0.00	0.15	6.2	300
B-5148	.13	.15	.07	3.98	99.84	.78	.00	.10	7.2	<296
B-5149	.15	.19	.05	2.46	99.52	.20	.00	.02	7.3	760
B-5150	.12	.17	.04	1.83	99.99	.03	.00	.00		

See footnotes at end of table.

TABLE 38.—*Chemical analyses of Kelvin soils*[1]—Continued

KELVIN GRAVELLY LOAM

Sample no.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-5151	1	0-4	68.59	2.84	16.37	0.55	1.28	3.67	3.92	0.57
B-5152	2	4-8	67.68	3.10	17.00	.59	1.22	3.58	3.78	.55
B-5153	3	8+	73.90	1.29	14.05	.17	.78	4.16	3.68	.21

Sample no.	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[2]	CO_2[3]	N	pH	Soluble salts
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Parts per million*
B-5151	0.07	0.05	0.04	2.18	100.13	0.64	0.00	0.06	6.7	<298
B-5152	.07	.03	.08	2.46	100.14	.41	.00	.05	6.4	340
B-5153	.03	.03	.09	.83	99.72	.25	.00	.00	------	------

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[1] Determinations by Glen Edgington.
[2] By combustion method ($CO_2 \times 0.471$).
[3] CO_2 of the carbonates.

The colloid analyses (table 39) show the usual uniformity of composition of colloid within each profile. The uniformity is the more apparent in these profiles by reason of the absence of carbonates. The higher iron content of the sandy loam soil, compared with gravelly loam, still appears in the colloids but the marked difference in magnesium, calcium, and sodium oxides has disappeared. The higher content potassium oxide in the gravelly loam soil still obtains in the colloids. The differences shown in the minor constituents of soils have largely disappeared in the colloids. No colloid was obtainable from the parent rocks.

TABLE 39.—*Chemical analyses of Kelvin soils colloids*

KELVIN SANDY LOAM COLLOID

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-5147	1	0- 1	5	49.10	9.41	22.38	2.52	1.79	1.35
B-5148	2	1- 8	11	49.70	8.20	24.68	2.38	1.63	1.00
B-5149	3	8-20	2	48.50	9.62	24.05	2.67	1.89	.67

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[1]	CO_2[3]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-5147	0.58	0.38	0.25	0.19	0.15	12.35	100.45	4.22	0.05	0.24
B-5148	.36	.42	.18	.12	.14	11.95	100.72	2.63	.01	.12
B-5149	.57	.32	.30	.12	.13	10.97	100.41	1.57	.03	.09

See footnotes at end of table.

TABLE 39.—*Chemical analyses of Kelvin soils colloids*—Continued

KELVIN GRAVELLY LOAM COLLOID

Sample no.	Horizon	Depth	Colloid extracted	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-5151	1	0-4	3	50.01	7.37	24.20	2.37	1.20	2.49
B-5152	2	4-8	6	51.03	7.30	24.12	2.47	1.31	2.26

Sample no.	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[1]	CO_2[2]	N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
B-5151	0.65	0.42	0.20	0.16	0.13	11.01	100.21	3.07	0.01	0.19
B-5152	.43	.51	.17	.10	.14	10.71	100.55	2.59	.05	.15

[1] By combustion method ($CO_2 \times 0.471$).

[2] CO_2 of the carbonates.

The derived data (table 40) show some interesting relations. The greater quantity of iron in the parent material and the colloid of the sandy loam is reflected in the small variation of the silica-sesquioxide ratios but does not appear in the silica-alumina ratios to so marked a degree. The silica-base ratios indicate the removal of bases to about the normal content of the dry-land soils. The lower degree of hydrolysis of the gravelly loam colloid is perhaps reflected in the lower content of combined water and of the combined water of the soil acids of the first and second horizons as compared with the second and third horizons of the sandy loam. Since these two colloids are relatively little affected by the presence of organic matter and not at all by carbonates the colloid may be regarded as a normal hydrolytic product of rock decomposition under limited rainfall. The empirical composition is, therefore, of some special interest and is here given in advance of the general discussion. Following the general form of expression used in a recent study (*11*), the composition of the inorganic soil acid for the two profiles may be written: $2.5H_2O.Al_2O_3.3.5SiO_2$. If all the iron oxide be considered as combined with the silicate it may be written as: $2.1H_2O.M_2O_3.2.9SiO_2$, ($M = Fe + Al$).

TABLE 40.—*Derived data: Kelvin soils colloids*

KELVIN SANDY LOAM COLLOID

Sample no.	Horizon	Depth	Molecular ratio						Combined water	Combined water of the soil acid[3]
			$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}^1}$	$\frac{SiO_2}{H_2O^2}$		
		Inches							*Percent*	*Percent*
B-5147	1	0- 1	2.93	13.83	3.71	0.269	6.98	1.44	8.08	10.65
B-5148	2	1- 8	2.81	16.05	3.41	.212	7.90	1.32	9.31	11.49
B-5149	3	8-20	2.67	13.35	3.33	.249	6.96	1.26	9.37	11.65

KELVIN GRAVELLY LOAM COLLOID

Sample no.	Horizon	Depth	$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}^1}$	$\frac{SiO_2}{H_2O^2}$	Combined water	Combined water of the soil acid[3]
B-5151	1	0- 4	2.93	17.99	3.50	0.194	7.07	1.48	8.02	10.43
B-5152	2	4- 8	3.00	18.50	3.58	.193	7.39	1.45	8.10	10.45

[1] Carbonates deducted.

[2] Combined water plus water equivalent of the bases.

[3] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.

HYGROSCOPIC RELATIONS

The authors (*6*) presented, in connection with a study of the fractionation of soil colloids, data which indicated that the ratio between the water vapor absorbed by soil colloids over 3.3 percent sulphuric acid (99 percent humidity) and over 30 percent sulphuric acid (75 percent humidity) at 35° C. is a function of the colloid composition even though the absolute quantities as well as the ratios vary with particle size. Later Brown, Rice, and Byers (*7*) in a study of claypan soil colloids emphasized the relation between colloid composition and water vapor absorption relations and further pointed out that in the soils studied the vapor absorption of the surface colloids was uniformly lower than in the colloids from the remainder of the profile.

In the present study it seemed desirable to extend the examination of these relations in order to determine what relations are characteristic of the dry-land soils, and if possible to determine definitely the cause or causes of the lower absorption of water vapor by the surface colloid at high humidity. In order to attain these ends all the colloids were air-dried and their absorptive capacities determined at 99, 75, and 50 percent humidities. They were also subjected to repeated wetting and drying treatments. These were carried out as follows: After obtaining the normal absorption data the colloids were heated at 105° C. overnight and an equal weight of water was added and the colloid allowed to air-dry for 2 days. It was again heated at 105° overnight. This treatment was repeated five times, after which the absorption values were again determined. This treatment was for the purpose of determining whether the cause of low surface absorption may be attributed to irreversible dehydration of the surface soil colloid under field conditions. The results obtained are given in table 41.

TABLE 41.—*Water-vapor absorption of colloids and absorption ratios*

SCOBEY LOAM

Sample no.	Horizon	Depth	Air-dried samples						Alternately heated and wetted 5 times					
			Water vapor absorbed over—			Absorption ratio			Water vapor absorbed over—			Absorption ratio		
			3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30.0\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$
		Inches	*Percent*	*Percent*	*Percent*				*Percent*	*Percent*	*Percent*			
10660	1	0–1½	28.44	12.06	8.44	2.36	3.37	1.43	23.72	10.10	7.56	2.35	3.14	1.34
10661	2	1½–5	29.09	13.70	9.56	2.12	3.04	1.43	25.95	12.18	9.47	2.13	2.74	1.29
10662	3	5–13	33.46	16.77	12.11	2.00	2.76	1.38	29.86	15.75	12.58	1.90	2.37	1.25
10663	4	13–20	34.40	16.48	12.19	2.09	2.82	1.35	30.46	15.85	12.50	1.92	2.44	1.27
10664	5	20–24	32.93	14.70	10.88	2.24	3.03	1.35	29.18	14.16	11.10	2.06	2.63	1.28
10665	6	24+	35.41	14.93	11.15	2.37	3.18	1.34	31.19	14.83	11.64	2.10	2.68	1.27

SPEARFISH SILT LOAM

Sample no.	Horizon	Depth	3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30.0\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$
B-1066	1	0–12	30.05	13.10	9.05	2.29	3.32	1.45	26.17	12.22	9.17	2.14	2.85	1.33
B-1067	2	12–24	28.08	9.24	5.90	3.04	4.71	1.57	24.86	9.31	6.18	2.67	4.02	1.49
B-1068	3	[1]28–42	28.60	8.80	5.43	3.25	5.27	1.62	25.89	8.89	5.71	2.91	4.53	1.56
B-1069	4	[1]60–72	28.66	8.30	5.07	3.45	5.65	1.64	25.01	8.32	5.29	3.01	4.73	1.57

TABLE 41.—*Water-vapor absorption of colloids and absorption ratios*—Continued

BADLANDS SILT LOAM

Sample no.	Horizon	Depth	Air-dried samples						Alternately heated and wetted 5 times					
			Water vapor absorbed over—			Absorption ratio			Water vapor absorbed over—			Absorption ratio		
			3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$
		Inches	*Percent*	*Percent*	*Percent*				*Percent*	*Percent*	*Percent*			
B-1041	1	0-1	32.79	15.23	10.92	2.15	2.99	1.39	30.77	13.69	9.98	2.25	3.08	1.37
B-1042	2	1-12	34.40	17.00	12.29	2.02	2.80	1.38	33.33	16.02	11.65	2.08	2.86	1.38
B-1043	3	12-30	36.30	16.40	11.92	2.21	3.05	1.38	33.53	15.87	11.66	2.11	2.88	1.36
B-1044	4	[1]72-84	37.11	18.13	13.71	2.05	2.71	1.32	32.76	17.95	13.64	1.82	2.40	1.32
PIERRE LOAM														
B-858	1	0-8	30.00	14.24	10.32	2.11	2.91	1.38	28.43	13.00	9.41	2.19	3.02	1.38
B-895	2	8-18	29.92	14.55	10.70	2.01	2.73	1.36	28.31	13.36	9.81	2.12	2.89	1.36
B-894	3	18-40	30.50	14.41	10.56	2.12	2.89	1.36	27.86	13.23	9.71	2.11	2.87	1.36
B-857	4	40-60	30.15	13.87	10.30	2.27	3.06	1.35	27.44	12.89	9.40	2.13	2.92	1.37
B-893	5	60-74	27.70	12.90	9.59	2.15	2.89	1.35	26.46	12.14	8.88	2.18	2.98	1.38
PECOS SANDY LOAM (VIRGIN)														
B-722	1	0-9	30.62	14.54	10.44	2.11	2.94	1.39	28.05	14.00	10.60	2.00	2.65	1.32
B-723	2	9-18	31.00	15.33	10.85	2.02	2.86	1.41	28.29	14.78	11.28	1.91	2.51	1.31
B-724	3	18-34	31.68	15.63	11.18	2.02	2.83	1.39	28.70	15.15	11.33	1.90	2.53	1.34
B-725	4	34-48	30.50	15.28	10.78	2.00	2.83	1.42	28.06	14.67	10.93	1.91	2.57	1.34
B-726	5	48-71	32.90	16.47	11.90	2.00	2.77	1.39	29.56	16.00	12.18	1.85	2.43	1.31
B-727	6	71-83	33.92	17.03	12.36	1.99	2.75	1.37	30.18	15.57	11.18	1.94	2.70	1.39
B-728	7	83-95	35.21	18.17	13.27	1.94	2.65	1.37	32.23	16.52	11.88	1.95	2.71	1.39
PECOS SANDY LOAM (IRRIGATED)														
B-713	1	0-9	30.20	15.05	11.19	2.01	2.70	1.34	28.69	14.64	11.48	1.82	2.32	1.27
B-714	2	9-18	31.28	15.09	11.63	1.99	2.69	1.35	27.66	15.28	11.90	1.81	2.32	1.28
B-715	3	18-35	31.70	16.01	11.02	1.98	2.87	1.45	28.83	15.94	12.50	1.81	2.31	1.27
B-716	4	35-47	31.23	15.54	11.12	2.01	2.81	1.40	27.91	15.23	12.00	1.83	2.33	1.27
B-717	5	47-53	28.67	13.87	9.71	2.07	2.95	1.43	25.50	13.46	10.20	1.90	2.50	1.32
B-718	6	53-64	26.47	12.73	8.72	2.08	3.03	1.46	23.93	12.34	9.24	1.94	2.59	1.33
B-719	7	64-82	28.10	13.78	9.60	2.04	2.93	1.44	25.63	13.30	9.95	1.93	2.58	1.34
B-720	8	82-90	29.16	13.83	9.68	2.11	3.01	1.43	26.41	13.49	10.26	1.96	2.58	1.31
B-721	9	90-101	32.58	15.60	10.88	2.09	2.99	1.43	28.80	15.13	11.53	1.90	2.50	1.31
PIMA CLAY ADOBE (VIRGIN)														
B-706	1	0-9	36.27	17.02	12.97	2.13	2.80	1.31	32.72	17.28	13.66	1.89	2.40	1.26
B-707	2	9-29	35.04	17.28	13.03	2.03	2.69	1.32	32.00	17.22	13.55	1.87	2.36	1.27
B-708	3	29-41	35.22	17.49	13.58	2.01	2.59	1.29	32.21	17.77	14.05	1.81	2.29	1.26
B-709	4	41-45	34.78	17.96	13.85	1.94	2.51	1.30	32.51	18.08	14.57	1.79	2.23	1.24
B-710	5	45-49	34.44	17.73	13.60	1.94	2.53	1.30	32.12	18.07	14.11	1.78	2.28	1.28
B-711	6	49-54	34.60	17.16	13.23	2.01	2.61	1.30	31.85	16.98	13.60	1.88	2.34	1.25
B-712	7	54-84	------	------	------	------	------	------	------	------	------	------	------	------
PIMA CLAY ADOBE (IRRIGATED)														
B-700	1	0-9	34.62	16.80	12.75	2.06	2.72	1.32	32.80	16.30	12.80	2.01	2.56	1.28
B-701	2	9-21	36.26	17.77	13.84	2.04	2.62	1.28	32.75	17.53	14.13	1.87	2.32	1.24
B-702	3	21-48	35.27	17.58	13.86	2.01	2.54	1.27	32.95	16.70	13.06	1.97	2.52	1.28
B-703	4	48-51	35.35	17.54	13.64	2.02	2.59	1.29	33.19	17.14	13.79	1.93	2.41	1.24
B-704	5	51-58	35.65	17.67	13.54	2.02	2.63	1.31	32.53	17.31	13.69	1.88	2.38	1.26
B-705	6	58-89	------	------	------	------	------	------	------	------	------	------	------	------

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[1] Only portion of profile taken.

TABLE 41.—*Water-vapor absorption of colloids and absorption ratios*—Continued

KELVIN SANDY LOAM

Sample no.	Horizon	Depth	Air-dried samples						Alternately heated and wetted 5 times					
			Water vapor absorbed over—			Absorption ratio			Water vapor absorbed over—			Absorption ratio		
			3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30.0\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$
		Inches	*Percent*	*Percent*	*Percent*				*Percent*	*Percent*	*Percent*			
B-5147	1	0- 1	31.96	15.30	11.68	2.09	2.74	1.31	28.37	13.68	10.17	2.07	2.79	1.34
B-5148	2	1- 8	31.90	16.76	12.60	1.90	2.53	1.33	29.51	15.30	11.42	1.93	2.58	1.34
B-5149	3	8-20	30.47	14.89	11.07	2.05	2.75	1.34	27.02	13.28	9.85	2.03	2.75	1.34
B-5150	4	20+	------	------	------	------	------	------	------	------	------	------	------	------

KELVIN GRAVELLY LOAM

Sample no.	Horizon	Depth	3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	3.3% H_2SO_4	30% H_2SO_4	42.5% H_2SO_4	$\frac{3.3\%\ H_2SO_4}{30.0\%\ H_2SO_4}$	$\frac{3.3\%\ H_2SO_4}{42.5\%\ H_2SO_4}$	$\frac{30.0\%\ H_2SO_4}{42.5\%\ H_2SO_4}$
B-5151	1	0-4	26.47	12.00	8.64	2.21	3.06	1.39	24.15	10.95	7.64	2.21	3.16	1.43
B-5152	2	4-8	29.84	14.48	10.40	2.06	2.87	1.39	26.35	12.96	9.17	2.03	2.87	1.41
B-5153	3	8+	------	------	------	------	------	------	------	------	------	------	------	------
Mean	----	------	31.98	15.19	11.11	2.16	2.97	1.38	29.03	14.54	11.04	2.10	2.78	1.33

The hygroscopic data and the ratios for air-dried samples (table 41) bring into clear relief some rather important relations. The mean value of the coefficient of absorption at 99-percent humidity for the 10 profiles reported is 31.98 percent. The maximum value is 37.11 and the minimum 26.47 percent. A portion of these variations is due to inaccuracies, inherent in the method employed, despite the fact that all the values recorded are the mean of duplicate determinations. A part of the variation is to be ascribed to variations in organic matter and carbonate content. The mean percentage absorption of the colloids at 75-percent humidity is 15.19 percent with a variation between a maximum of 18.17 and a minimum of 8.3 percent. These latter values are of special interest because numerically they are approximately equal to the heat of wetting (*2*). The mean value of the absorption at 50-percent humidity is 11.11 percent with a variation between the limits of 13.86 and 5.07 percent. It may be noted that the low values at both 50- and 75-percent humidity are in the subsurface soil colloids of the Spearfish loam and are undoubtedly associated with its abnormal composition (p. 44).

The variations which are produced by what may be termed impurities of the colloid should disappear in large part when the ratios of the determined values are calculated. The mean value of the ratio of vapor absorbed at 99- as compared with that at 75-percent humidity is 2.16 and differs from the mean value of the profiles of other dry-land soils, previously reported, only by 0.08 (*7*). The limits are 3.45 and 1.90. Again, the maximum abnormal value is in the colloid from the Spearfish. If this soil be excluded the maximum ratio is 2.36 in the surface soil of the Scobey loam. The mean ratio for the quantities of vapor absorbed at 99- as compared with that at 50-percent humidity is 2.97 with extreme limits, excepting in the Spearfish colloid, of 3.37 and 2.51. The ratio of the absorption at 75- as compared with 50-percent humidity has a mean value of 1.38 and limiting values, excluding the Spearfish profile, of 1.45 and 1.27.

The abnormal water-vapor absorption values and ratios of the Spearfish colloids are in accord with their abnormal chemical composition (table 7) and the variation is roughly proportional to the magnesium-oxide content of the colloid. It seems apparent that the Spearfish is either a very immature colloid with respect to the extent of hydrolysis or that the magnesium colloid has different properties from those containing less magnesia. The absorption values and ratios of the bentonite colloid, the analysis of which is given in table 11, were also determined. The ratio for the absorption at 99- to that at 75-percent humidity is 2.30. For a sample of halloysite the corresponding ratio is 7.02. (See general discussion.)

Whatever may be the contributing causes of water-vapor absorption and their relation to the chemical composition of the colloids, the conclusion is inescapable that the water-vapor-absorption ratios of the colloids of the dry-land soils are characteristics of this great group of soils. This is particularly true of the 99- to 75-percent humidity ratio which, including the soils reported (7), have for 17 profiles a mean value of 2.13.

The mean water-vapor absorption of the surface layer of these 10 profiles is 31.14 percent while that of the second horizon of the profiles is 31.68. The differences between these quantities is not so great as those previously reported (7) in which the difference recorded between the A and B horizons for 8 soils is 5.69 percent. In the colloids (described in this bulletin) there is also a smaller difference between the organic matter of the first and second horizons. The mean value of the organic matter of the surface horizon is 4.30 percent and of the second layer is 2.83 percent, a difference of but 1.47 percent. In the data of the 8 soils reported (7), these percentages and their differences are respectively 7.27, 1.96, and 5.31 percent. It is difficult to avoid connecting the two phenomena although there seem to be insuperable difficulties in attempting to ascribe a causal relationship.

Among the possible explanations of the lower water-vapor absorption of the surface soils is that of relatively irreversible dehydration of the surface soil colloids by more frequent periods of wetting and drying than are experienced by those of the subsurface horizons, of comparable material. In order to test the validity of this assumption the water-vapor absorption was determined on the same samples after repeated wetting and drying. The data with the consequent ratios are given in the last six columns of table 41. It will be observed from the data that in all cases at high humidity the process results in lowered absorption not only of the surface horizon but of all the others as well. The mean reduction for all the profiles after repeated wetting and drying is 2.95 percent (dry colloid weight) at 99-percent humidity, 0.65 percent at 75-percent humidity, and 0.07 percent at 50-percent humidity. For the surface layers the reduction is 2.95, 1.16, and 0.35 percent at the corresponding humidities. It will be observed that the effect of the wetting and drying process practically disappears at lower humidities.

It must be frankly confessed that the data available still leave unanswered the question as to the cause of the observed results. It seems wholly improbable, despite the numerical relations, that the effect of the repeated wetting and drying is upon the organic matter since the colloids throughout the profile are essentially equally affected. On the other hand, were the effect due primarily to wetting and drying the surface soil colloids should be markedly less affected. This is not the case. If the effect is to be ascribed to particle size then since the colloids in question are all extracted in the same manner and the attempt made to limit the maximum size to 0.3μ, the differences between these particular soil colloids in respect to size of particles should be small and the differences in water-vapor absorption should likewise be small. This is the case. Nevertheless, the question may not be considered answered satisfactorily. Observations in this connection will be continued.

CARBON-NITROGEN RATIOS

In a recent publication Anderson and Byers (*4*) have pointed out certain relations of the carbon-nitrogen ratio and the great soil groups and have supplemented the observations of Leighty and Shorey (*28*) with respect to the variations with depth. In the present studies it therefore seemed well worth while to call attention to these ratios in the soils and colloids, particularly because information on the carbon-nitrogen ratio of colloids is very meager.

The ratios are assembled in table 42. In both the soils and the colloids the general result is a decrease of the ratio with depth, though some exceptions are found. In the soils the quantities of organic matter at lower levels are sometimes so small as to make the data unreliable, particularly when the carbonate content is high. Although the carbon-nitrogen ratios of the dry-land soils are apparently more constant than in the case of other great groups of soils (*4*) it is quite evident that even here a nitrogen determination does not furnish an adequate measure of the organic-matter content. The mean of the surface horizons of this series is 10.1 for the soils and 8.9 for the colloids. These values are in accord with mean values previously obtained. It appears that the dispersed and water-insoluble organic colloid of these arid soils has a higher nitrogen content than the total organic matter.

TABLE 42.—*Carbon-nitrogen ratios*[1] *of the soils and their colloids*

Sample no.	Depth	C/N ratio of—	
	Inches	Soil	Colloid
SCOBEY LOAM			
10660	0 - 1½	9.6	8.3
10661	1½- 5	9.1	8.8
10662	5 -13	5.7	8.4
10663	13 -20	8.2	8.6
10664	20 -24	7.8	8.0
10665	24+	6.5	7.7
SPEARFISH SILT LOAM			
B-1086	0-12	9.5	6.9
B-1087	12-24	5.7	8.2
B-1088	28-42	4.0	5.5
B-1089	60-72	4.0	5.8
BADLANDS SILT LOAM			
B-1041	0- 1	10.3	9.4
B-1042	1-12	8.2	9.7
B-1043	12-30	6.7	9.8
B-1044	72-84	4.1	9.6
PIERRE LOAM			
B-858	0- 8	11.2	10.4
B-895	8-18	10.0	10.7
B-894	18-40	10.1	9.2
B-857	40-60	6.2	10.0
B-893	60-74	9.5	10.4

Sample no.	Depth	C/N ratio of—	
	Inches	Soil	Colloid
KEITH SILT LOAM			
9222	0 - ½	13.0	8.3
9223	½- 3½	11.2	7.6
9224	3½-14	11.3	10.6
9225	14 -21	11.0	7.5
9226	21 -33	8.7	6.1
9227	33 -40	14.8	7.2
HAYS SILTY CLAY LOAM			
6842	2-10	10.9	7.9
6843	10-20	9.2	6.1
6844	20-33	9.4	4.0
6845	33-47	6.2	3.4
6846	47-60	2.5	2.2
6847	60-72	2.7	2.0
PULLMAN SILTY CLAY LOAM			
4574	0- 5	14.0	(2)
4575	10-20	10.1	(2)
4576	30-40	11.1	(2)
PECOS SANDY LOAM (VIRGIN)			
B-722	0- 9	11.0	7.6
B-723	9-18	10.2	7.1
B-724	18-34	12.9	6.9
B-725	34-48	8.3	6.5
B-726	48-71	11.0	3.4

Sample no.	Depth	C/N ratio of—	
	Inches	Soil	Colloid
PECOS SANDY LOAM (IRRIGATED)			
B-713	0- 9	10.5	9.8
B-714	9-18	9.2	10.3
B-715	18-35	9.2	6.8
B-716	35-47	9.7	6.0
B-717	47-53	10.3	6.8
B-718	53-64	9.9	6.3
PIMA CLAY ADOBE (VIRGIN)			
B-706	0- 9	5.0	7.7
B-707	9-29	8.1	8.5
B-708	29-41	5.7	8.3
B-709	41-45	7.6	5.9
B-710	45-49	2.6	7.9
B-711	49-54	(2)	8.4
PIMA CLAY ADOBE (IRRIGATED)			
B-700	0- 9	9.6	8.5
B-701	9-21	8.0	8.1
B-702	21-48	(2)	6.8
B-703	48-51	(2)	7.3
B-704	51-58	(2)	7.7
KELVIN SANDY LOAM			
B-5147	0- 1	10.1	10.2
B-5148	1- 8	4.5	12.7
B-5149	8-20	5.8	10.1
KELVIN GRAVELLY LOAM			
B-5151	0- 4	6.2	9.4
B-5152	4- 8	4.8	10.0

[1] (Organic matter×0.58)÷nitrogen.

[2] No nitrogen or organic matter recorded.

GENERAL DISCUSSION

In a recent publication (*7*) the writers have presented data which indicate that the colloids of the series of dry-land soils reported may be regarded as derived from a hypothetical acid, pyrophyllic acid, since their silica-sesquioxide ratio closely approximates the composition of pyrophyllite. In a more recent publication Byers, Alexander, and Holmes (*11*) also point out that each of the great groups of soils appears to have a colloid composition which may be expressed, so far as the fundamental inorganic acid is concerned, by a definite relation of silica, alumina, and water. In the case of the typical Chernozem soil this relation is not far from that represented by the expression $3H_2O.Al_2O_3.4SiO_2$. In the Chernozems it is necessary to consider the iron content as chiefly combined with the silica as part of the acidoid complex. Therefore the composition is expressed as $3H_2O.M_2O_3.4SiO_2.(M=Al \text{ and } Fe)$. In the series of soils here presented the greater part of the profiles is from areas even less subject to leaching than are true Chernozem soils. It is therefore of special interest to consider the colloidal composition with reference to this relationship.

In order to present the pertinent data in such form as to permit a comprehensive survey of the whole group of soils, profile averages of the derived data are assembled in table 43. Averages of ratios are permissible in these profiles because of the small variations in composition within each profile, which warrant the inference that we are dealing with essentially the same material in each profile. Included in this table are the water-alumina and water-sesquioxide ratios. The mean values of the 13 profiles are given at the bottom of the table.

It would appear, therefore, that the dry-land soils represented in these profiles have a colloid composition with a silica-sesquioxide ratio of 3.31 with an average deviation from the mean of 0.32. It would appear, therefore, that where excessive deviations are found an explanation should also be found. The two most marked deviations are in the cases of the Spearfish and Badlands colloids. It has already been pointed out that in the Spearfish soil the influence of the parent material is so marked that the colloid cannot be considered a truly representative alumino-silicate for this region. It resembles the high magnesium soils reported by Robinson and his coworkers (*40*). Further, the parent rock is Triassic shale with a relatively high content of free iron oxide. The Badland colloid is so high in silica content that it appears reasonable to regard it as the closest available approach to a colloid of the montmorillonite type (*8*). It is, however, possible that the Brule clay from which it is derived contains some free silica of colloidal dimension.

TABLE 43.—*Review of data: colloids* [1]

Soil type	Molecular ratio								Combined water of the soil acid [4]	Absorption ratio [5]
	$\frac{SiO_2}{Fe_2O_3.Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Fe_2O_3}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$ [2]	$\frac{SiO_2}{H_2O}$ [3]	$\frac{H_2O}{Al_2O_3.Fe_2O_3}$	$\frac{H_2O}{Al_2O_3}$		
									Pct.	
Scobey loam	3.15	13.35	4.20	0.310	7.19	1.49	2.11	2.82	10.58	2.20
Spearfish silt loam	2.67	18.61	3.13	.166	2.89	1.14	2.34	2.74	11.94	3.01
Badlands silt loam	4.41	23.44	5.42	.232	6.83	1.93	2.28	2.81	9.07	2.11
Pierre clay	3.15	15.95	3.89	.244	6.18	1.64	1.95	2.32	9.59	2.13
Keith silt loam	3.68	20.30	4.50	.222	5.78	1.46	2.46	3.04	11.20	2.13
Hays silty clay loam	3.50	19.07	4.29	.225	5.44	1.43	2.45	3.00	11.15	------
Pullman silty clay loam	3.09	16.20	3.71	.230	6.00	1.52	2.03	2.44	10.37	[6] 1.90
Pecos sandy loam (virgin)	3.36	19.14	4.08	.216	4.92	1.23	2.73	3.32	12.60	2.01
Pecos sandy loam (irrigated)	3.29	18.60	3.98	.210	4.84	1.24	2.65	3.21	12.45	2.04
Pima clay adobe (virgin)	3.51	17.46	4.38	.252	5.07	1.60	2.21	2.74	10.06	2.01
Pima clay adobe (irrigated)	3.50	17.71	4.37	.249	5.68	1.61	2.17	2.71	10.14	2.03
Kelvin sandy loam	2.80	14.41	3.48	.243	7.38	1.34	2.09	2.60	11.26	2.01
Kelvin gravelly loam	2.90	18.24	3.54	.193	7.23	1.40	2.04	2.43	10.44	2.13
Mean	3.31	17.90	4.07	.230	5.82	1.47	2.27	2.78	10.83	2.14

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[1] Profile averages.
[2] Carbonates deducted.
[3] Combined water plus water equivalent of the bases.
[4] Combined water plus water equivalent of the bases, corrected for organic-matter and carbonate content.
[5] Water absorbed over 3.3 percent H_2SO_4 divided by water absorbed over 30 percent H_2SO_4.
[6] Calculated from data from Technical Bulletin 228 (*5, p. 10*, Amarillo silty clay loam).

To gain some information on this point a sample of the colloid was sent to S. B. Hendricks of the Division of Fertilizer Investigations for X-ray examination. Also a sample was treated with constant-boiling hydrochloric acid and the residue examined. The X-ray patterns in both samples show not only the presence of quartz but also of a line given by fused quartz and silica gel. It seems probable, therefore, that the high ratio in the Badlands colloid is due to free silica rather than a silicate complex. The Keith silt loam has a slightly abnormal average deviation from the mean but a very small quantity of free silica would produce the result observed. The deviations shown by the Kelvin soils are readily accounted for by the presence of free iron oxide as indicated by the color of the soil and even more emphatically by the color of the colloid. An additional influence tending to lower these ratios will be discussed later.

Were the silica of these colloids wholly associated with alumina to form an acid complex the mean silica-alumina ratio 4.07 would be almost the theoretical ratio of pyrophyllite. This assumption cannot be sustained by the evidence. The average deviation from this mean is 0.41. The only colloids having ratios markedly exceeding this average deviation are the Spearfish and Badlands colloids. The explanations in these cases are the same as in the case of the silica-sesquioxide ratio. The smaller excess in deviation of the Kelvin colloid will be discussed later.

The mean water-sesquioxide ratio, 2.27 shows an average deviation of 0.20. The only soils showing marked deviation are the two profiles of the Pecos sandy loam and the Pierre clay.

The mean water-alumina ratio, 2.78, shows an average deviation of 0.23. Again only in the case of the two profiles of the Pecos series is there a very marked excess above the average. A less marked divergence occurs in the Pierre clay. A satisfactory explanation in these cases does not appear evident from the data. Indeed in view of the known uncertainties in the evaluation of the combined water of the soil acids, the degree of uniformity of the water-sesquioxide and water-alumina ratios is quite remarkable.

The silica-total base ratios have an average value of 5.82 with an average deviation of 0.84. It will be noted that in this ratio the average deviation is extremely wide and the ratios show in several cases extreme divergence. This is particularly the case with the Scobey and Spearfish colloids, in opposite directions, and the Kelvin profiles.

This wide variation in base content is to have been expected by reason of difference in rainfall and permeability of the soils. It is emphasized in the case of the Scobey loam since added weight is given to the leached portion of the soil though the horizons are taken above a depth of 13 inches. The lower portion of the profile is not so widely divergent from the mean. In the case of the Spearfish silt loam the high magnesium content is responsible for the low ratio and further emphasizes the abnormal character of the colloid. In the case of the two profiles of the Kelvin colloid the low base content is apparently due to the shallow soil and the absence of carbonates to keep the colloid more nearly saturated with bases. In general the silica-base ratios are relatively high, the bases low, in all the surface horizons.

The average water-vapor absorption ratio is 2.14 with an average deviation of but 0.15. This is the most uniform of the colloid properties determined. The only excessively wide deviation is in the case of the

Spearfish colloid. There is little question that in this case the greater portion of the deviation is by reason of the free iron oxide present. Unpublished data indicate that iron oxide has a much higher ratio than have the dry-land colloids. The ratio for the high magnesium colloids (*40*) has not been determined.

From the total available data it appears that the inference is warranted that the dry-land soils approximate a colloid composition, expressed for the inorganic soil acid, which approaches closely the formula of pyrophyllic acid $3H_2O.Al_2O_3.4SiO_2$. The divergence from this ideal limit is greater as the iron content of the colloid increases and the greater the extent to which it is free iron oxide. The water equivalent should normally be less than the hypothetical maximum.

It is to be expected that the attainment of the idealized pseudo-equilibrium assumed would be modified by one or another of the soil-forming influences playing a predominant role. From their study of claypan soils in Nebraska (*7*) the writers were unable to establish a dominant role in rainfall over a range of 13 to 32 inches in which percolation of water through the soil profile could not be assumed to occur. The temperature range being very small the effect of surface drainage in these soils can be visualized but not estimated. In the present series of soils the rainfall ranges from 8.5 inches to 22.8 inches and no definite relation between colloid composition and rainfall appears to exist. While this is the case with dry-land soils it does not follow that it is true of all soils.

In order to consider more satisfactorily the possible relationship between the composition of the colloid acid and the temperature, the data concerning composition and temperature are arranged as in table 44. The empirical composition used for this purpose is the water-alumina-silica ratios of the profile averages. A study of this table brings out no consistent relation between the mean annual temperature over a range between 32.6° and 69.0° F. and the composition of the colloid acid. The colloids developed at 46.0° and 46.2° F., the Badlands and Spearfish, have essentially the same combined-water content, but the widest spread in silica content found in the soils examined. The mean composition of the two profiles of the Kelvin colloid have next to the lowest silica content and the highest mean annual temperature, 68.8° F. They also have a low water content. On the other hand, the next highest mean annual temperature corresponds to a soil with more than average water and a relatively high silica content.

If it be objected that temperature effects may be expected to be more marked in the surface portions of the profiles and that, therefore, such effects are concealed by the use of the mean values given in table 44, it appears that the surface colloid composition shows small variation from the mean values of each profile. These variations, however, show no consistent trend, and the mean values of the composition of the surface colloids of the ten soils show no significant difference from the mean values for the colloids of the whole profile. In view of the well recognized influence of temperature upon the composition of humid soil colloids, it may be noted that these effects result from the action of water. In these soils the relative absence of water minimizes effects of temperature.

TABLE 44.—*Relations between temperature, rainfall, and proportions of Al_2O_3, SiO_2, and H_2O in colloids from various soils*

Soil series	General location	Mean annual temperature	Mean annual rainfall	Formulae ratios of profile[1]			Formulae ratios of surface horizons		
				H_2O	Al_2O_3	SiO_2	H_2O	Al_2O_3	SiO_2
		° F.	*Inches*						
Scobey	McKenzie County, N. Dak.	39.8	13.67	2.82	1	4.20	3.10	1	4.14
Badlands	Interior, S. Dak.	46.0	14.54	2.81	1	5.42	2.69	1	5.28
Spearfish	Piedmont, S. Dak.	46.2	17.71	2.75	1	3.13	2.43	1	3.35
Pierre	Gregory County, S. Dak.	47.2	14.64	2.42	1	3.89	2.78	1	3.76
Keith	Dundy County, Nebr.	49.9	16.85	3.04	1	4.50	3.16	1	4.64
Hays	Hays, Kans.	54.3	22.8	3.00	1	4.29	2.65	1	4.25
Pullman	Masterson, Tex.	55.8	20.8	2.44	1	3.71	2.58	1	3.80
Pima	Mesilla Park, N. Mex.	61.2	8.50	[2] 2.72	1	4.88	[3] 2.47	1	4.02
Pecos	Carlsbad, N. Mex.	62.7	14.07	[2] 3.26	1	4.03	[3] 3.09	1	4.02
Kelvin	Florence, Ariz.	68.8	10.46	[2] 2.52	1	3.51	[3] 2.50	1	3.55
Mean				2.78		4.11	2.76		4.09

[1] Profile averages. [2] Average of 2 profiles. [3] Average of 2 samples.

If attention be turned to the effect of parent materials on the composition of the colloids, more satisfactory relationships can be noted. The abnormal composition of the immature Spearfish and Badlands soils is clearly ascribable to the influence of the parent material. The low silica and water content of the Kelvin colloids is influenced by the character of the granites which are their primary source, and this influence is supplemented by the absence of calcium carbonate. The other soils are influenced by the mixture of aeolian material, shales, and granites, which in varying degrees contribute to their origin. It is perhaps impossible, and certainly from available data, to trace the parts played by each in the variations of composition observed.

It would seem that in view of all the data available the following general inferences are warranted: The dry-land soils, including the Chernozem, Chestnut, and Gray soils are characterized by an inorganic colloid acid approximating the relation $3H_2O.Al_2O_3.4SiO_2$ with more or less replacement of the alumina by iron oxide. The pseudoequilibrium reached is a resultant of the effects of rainfall, temperature, vegetation, and drainage upon the parent material. The most important causes of deviations from normal composition are due to the character of the parent material. It is not to be assumed that a like group of inferences would be valid in considering related soil series in other great groups where percolation of water through the profile is the normal condition. The situation in such cases is under investigation.

Whether the hypothetical considerations presented are useful or warranted there remains this important fact—the dry-land colloids are strikingly similar.

SUMMARY

A study has been made of the mechanical and chemical composition of 13 soil profiles derived from soils developed under a rainfall ranging between 8.5 and 23 inches with a mean annual temperature range between 40° and 69° F. A field description is given of each soil series and of the particular profile examined. These descriptions include such information as is available concerning parent material, vegetation, and climate. The parent material of these soils is of varied type and includes granites, shales, and aeolian and alluvial materials.

The chemical and other characteristics of each profile and the effects of drainage, changes with depth, etc., are discussed in connection with the analytical data on each soil. This is followed by a general discussion of the relationships shown by the whole group. In addition to the detailed analyses the soluble salts and the pH values of the soils have been determined. The hydroscopic characteristics of the colloids have been determined at 99-, 75-, and 50-percent humidity.

The analytical results are presented in the form of tables relating to each soil, and tables of derived data relating to each colloid have been prepared. The colloids from these profiles have been extracted and analyzed. The carbon-nitrogen ratios of both soil and colloid have been determined and discussed. It is shown that the dry-land soils and colloids investigated have a carbon-nitrogen ratio which in the surface material is fairly uniform and lies below the ratio of 10:1. As a rule also this ratio decreases with depth.

It is shown that the composition of the inorganic soil acid of these 13 profiles has an average composition expressed by the mean silica-sesquioxide ratio 3.31, silica-alumina ratio 4.07, water-sesquioxide ratio 2.27, and water-alumina ratio 2.78.

The mean water-vapor absorption of the colloids at 99-percent humidity compared with that at 75-percent humidity has a mean value of 2.14. This is found to be the most uniform characteristic of the dry-land colloids.

It is inferred from the data that the dry-land soils under their environmental conditions tend to produce a colloid of the pyrophyllic acid type, or one dominated by an approach toward the ideal composition of the inorganic complex $3H_2O.Al_2O_3.4SiO_2$. Various influences modify the composition but in these soils the most effective cause of variation is assumed to be the parent material.

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