

PRELIMINARY REPORT

on the

SOILS OF COLORADO

by

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- * Recommended for correlation 1936 by Dr. F. A. Hayes.
 - ** Tentative series name and description.
 - *** Series name from communication with W. T. Carter.

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INTRODUCTION

Soils of Colorado have been subjected to very little study prior to the past two years. Soil surveys made from 1926 to 1931, chiefly of the irrigated sections in the Arkansas Valley and northern Colorado, give very good information concerning the areas mapped. However, these areas represent a very small percentage of the total area in eastern Colorado and there has been little attempt to show the relation of the various soils in the state to each other and to the great soil groups recognized in the United States.

It is the object of this paper to present the following:

1. A general discussion of some soils in this large area and their place in the great soil groups of the world.
2. A description of each soil series* recognized thus far, emphasizing the differences between closely related series.

GENERAL DISCUSSION OF AREA

Eastern Colorado is here considered as that portion of Colorado east of the Rocky Mountain range front. It represents an area of about 45,000 square miles.

The general topography of this area is that of a smooth plain sloping to the eastward, and modified by the valleys of the South Platte, Republican, and Arkansas rivers and their tributaries.

There are rather large areas of hilly to rough and broken topography. The larger of these areas include much of Las Animas County on both sides of Purgatoire River, the Black Forest region east of Palmer Lake, and the discontinuous areas north of South Platte River along the north state line. Elsewhere there are continuous areas of many square miles of nearly level to gently undulating topography.

Sandhill areas occupy several large and many small areas. The largest are south of South Platte River in Yuma and eastern Washington counties and south of Big Sandy Creek.

* Due to the preliminary nature of the study, many soil series names are tentative, and the soil descriptions are subject to revision.

The climate of the region is continental, sub-humid to semi-arid. The average maximum temperatures for July vary from 94° F. in the eastern part of the Arkansas Valley to 80° along the range front. Annual means are about 45° to 55° F. January daily minima are about 10° to 20° F.

Precipitation which comes in most years chiefly during the spring and summer varies from about 12 inches in the Arkansas Valley to slightly over 18 inches mean annual in the extreme northeastern part and in parts of the Black Forest region. In western Colorado, precipitation varies from under 7 to nearly 40 inches mean annual.

The western part of the state is occupied by high mountains, high mesas, steep-sided canyons, rather low desert areas, and rolling to hilly range lands. Only a few soils recognized in this large variable area are discussed here so little attention is given to its general description.

As might be expected near the mountains, the soils have formed on a great variety of parent materials. To prevent confusion, we have grouped these materials depending on their general physical and chemical characteristics, and have disregarded their geologic age in some instances. The groups are as follows:

1. Sands and soft sandstones.
2. Wind transported fine sands, silt, and clay (loess).
3. Mixed sands, gravel, clay, and limy sandstone (tertiary).
4. Limy shales and limestones (Benton age).
5. Clay shales (Pierre, Graneros, Dawson, etc.)
6. Non-calcareous (acid) arkose, sandstone, and conglomerate.
7. Chalkrock (Niobrara).

Any of the above groups, of course, may be mixed and (or) reworked.

Native vegetation includes a variety of tall grass prairie, short grass prairie, semi-desert, desert, and forest types.

SOILS

The soils in the region are quite variable as the range in climatic, biotic, topographic, and parent material factors would indicate.

The surface soils range in color from very dark grayish brown to very light grayish brown, and in texture from sand to clay. The subsoils have about the same range in color and texture as the surface soils, and in addition a wide range of structural conditions. Soil development is from new and immature to old and "post" mature. The soils may be grouped, in general, into - I, Zonal, and II, Intrazonal soils.

Zonal Soils

The Zonal soils are those that have been under the influence of the climatic, biotic, and parent material factors sufficiently long to have reached a more or less stable equilibrium. (Of course we can only estimate this state of equilibrium from observing topographic, vegetative, and soil profile characteristics.)

Intrazonal soils are those that have been unable to develop normally due to constant wind or water erosion, inert parent material, or those being recently deposited, or due to lack of good drainage.

The Zonal soils may be divided into groups dependent on the salient features of the soil profile, these features are in turn dependent on the conditions under which the soil developed. The Zonal soils are classified according to the system suggested by Marbut with some modifications. Only the soil groups thus far observed in Colorado are listed here.

A. Pedalfers

1. Podzols
2. Prairie soils

B. Pedocals

1. Dark brown (chestnut)soils
2. Brown soils - friable subsoils
3. Brown soils - semi-claypan subsoils (solonetzic)
4. Light brown soils (semi-desert)

Pedalfers

The Pedalfer group of soils includes all soils that do not have a zone of lime carbonate accumulation in the subsoil, or those in which the lime carbonate has been leached out of the upper few feet of the soil profile. Usually these soils are not developed in this latitude in regions of less than about 26 inches average annual precipitation. However, they have developed in eastern Colorado on parent materials very low in bases (chiefly calcium) and in areas close to high mountains where cool nights and considerable winter snowfall makes the precipitation of 15 to 20 inches much more effective than it is further out on the plains.

PODZOLS.--Podzols or podzolic forest soils have developed on the higher elevations in the Black Forest. They are at elevations above 7000 feet and have developed under a coniferous vegetation. Apparently the area of forested country is receding in some places as the podzol soils are found as much as one-half mile from the edge of the forested area, and modified podzol soils occur as much as five miles from the forest. The only podzol series recognized has been mapped by the Soil Conservation Service and is tentatively called Sylva.

Sylva Series.--The Sylva series belong to the podzol soil group, and are developed on Dawson arkose, which is a mixture of gravel, sand and clay. In general, the soils occur on slopes of 4 to 12 percent. The native vegetation is forest (*Pinus ponderosa*) with a very sparse growth of grasses among the trees.

Surface drainage is everywhere good, and runoff is rapid where the litter has been partially or fully removed.

The precipitation is between 17 and 20 inches per annum and the elevation is above 7000 feet above sea level.

The following description covers a typical profile of the gravelly sandy loam type examined in Sec. 20, T. 12 S., R. 65 W., 440 feet north of west quarter corner, and 75 feet east of road, El Paso County:

- 0"-1" Leaf litter consisting almost entirely of pine needles undecomposed.
- 1"-2" Dark gray structureless sandy gravelly loam.
- 2"-10" Very light grayish yellow to nearly white, single grain gravelly sandy loam. This is the leached or "gray layer" of the profile. In certain localities it attains a thickness exceeding two feet. In others it is only a few inches through. It seems to be about average thickness for the region at this point which is on a five percent slope.
- 10"-22½" Light brown to brown structureless to cloddy gravelly sandy loam, containing a large amount of clay. The layer is hard and brittle when dry and has a pronounced sticky gritty feel when moist. It is darkest in the upper 5-inch portion where the clay is also most abundant.
- 22½"-48" Very light grayish brown, slightly sticky but almost incoherent gravelly sand. The cementing material, probably feldspar clay (Kaolin) is sufficiently abundant to give the sand and gravel good coherence in position.

Below 4 feet in this particular profile the sand and gravel mixture contains little or no cementing material and is incoherent. It is very light yellowish-brown. The profile is not calcareous at any depth.

The gray layer of the gravelly sandy loam type is seldom laminated but in some of the finer textured types this structure is highly developed especially in the lower part of the leached horizon. The latter types locally show a thin iron cemented, ortstein layer in the B horizon.

Most of the Sylva soils have been pastured so heavily that a large part of the litter has either been eaten by the animals or has become so pulverized by trampling that it has eroded away. These soils have very slow moisture absorbing properties considering their large proportion of gravel and sand and it is only with aid of the "spongelike" forest litter that rains soak into the soil readily.

The dividing line between organic litter and mineral soil is not sharp in most areas of Sylva soils. This may be due to a mixing of the upper few inches of the mineral soil with organic matter through stock trampling. Or it may be caused by a slight accumulation of organic matter from the sparse growth of grasses during a time when the leaching of organic matter is not rapid. Both explanations may function in accounting for the organic matter.

PRAIRIE SOILS.---The soils in the higher altitudes surrounding the Black Forest and developed on non-calcareous parent materials show some

essential characteristics of prairie soils. They have no lime zone. There are indications of the downward movement of sesquioxides, and surface soils (in the more nearly level situations) are quite thick and dark grayish brown. These soils are similar to those of the dark brown Pedocal group in all respects except that they have no layer of accumulated lime carbonates and show no indication of such carbonates in any part of the soil profiles. They might in some ways be considered grassland podzols.

Falcon Series.---Soils of the Falcon series have developed on gravel sands and clays of the Dawson Arkose formation. They occur at elevations between 6500 and 7500 feet on rounded to gently undulating divides. Falcon soils occupy the parklike areas or grassland areas within and surrounding the forested areas of podzol soils in the Black Forest region.

Precipitation is from 16 to 18 inches per annum.

Native vegetation consists entirely of grasses, principally grama and buffalo grass, although western wheat grass is in disturbed situations, and wild rye occurs locally.

The following profile observed 935 feet west of east 1/4 corner, Section 20, Township 11 South, Range 66 West, is typical of the fine sandy loam type.

- 0"-4" Dark grayish-brown, single grain, friable, fine sandy loam, mulch-like when dry.
- 4"-12" Dark grayish-brown (similar in color to layer above), friable single grain, fine sandy loam. This layer is slightly more compact in position than the overlying one.
- 12"-18" Same as layer above except slightly lighter in color and a trifle more compact in position. This is the heaviest layer of the profile but its increased density is hardly noticeable except by comparison with the layers above and below. It is a fine sandy loam which breaks into clods of irregular size and shape.
- 18"-40" Light grayish brown, friable, structureless, fine sandy loam. This horizon is more distinctly brown and less grayish-brown than the one above. It includes layers that are slightly heavier than the remainder of the matrix and which contain scattered rusty-brown splotches and spots, but the color as a whole is quite uniform and the soil shows no evidence of having been poorly drained. The material is rather firm in its natural position but a lump of it can be easily crushed between the fingers and thumb.
- 40" - Incoherent to only slightly coherent, very light grayish-brown or grayish-yellow fine sand which gives way at 6 feet to light brown fine to medium sand containing a small amount of fine quartzitic gravel. The entire horizon has enough clay to make it slightly sticky when moist.

All horizons merge in texture, color and consistency. The section simply becomes gradually lighter in color and looser with depth although

the third layer (12"-18") is slightly heavier than any other as previously mentioned.

There are no carbonates to a depth of 7 feet and roadside cuts give no effervescence to a much greater depth (15').

Hamilton Series.--Little can be said concerning this series as it has been observed in only a few places in Rio Blanca and Moffat Counties and has not been mapped on detailed surveys.

To a depth of 2 feet or slightly more this soil is very dark grayish brown granular friable very fine sandy loam to clay loam. This is underlaid by 10 or 12 inches of somewhat dense granular brown clay loam. The underlying C horizon is light brown, non-calcareous cloddy loam. Lime may be present below 6 feet but apparently forms no lime zone. The parent materials are sands and clays of low or medium lime content. They are chiefly of tertiary age.

These soils occur on undulating to rolling topography and are considered good farm soils. The precipitation is between 17 and 19 inches mean annual, a large proportion of which falls as snow. Natural vegetation is a mixture of sage and tall grasses.

The Hamilton series differ from prairie soils of central United States in that they are developed in situations that makes them partially residual and partially colluvial in origin. The parent tertiary materials are also probably lower in lime content than most parent materials of Prairie soils further east.

Other Prairie Soils.--Several other soil series in eastern Colorado do not have a lime zone, but for various reasons (noted later) they will be classed with other soil groups.

Pedocals

The pedocal group includes soils that have developed a zone of lime accumulation. The precipitation falling on these soils does not generally penetrate below a depth where the roots of the native plants will remove it.

This group includes all of the soils in eastern Colorado except those developed on porous sands and those developed on parent materials very low in calcium (as previously described).

The soils normally developed in the eastern (or sub-humid part) of the pedocal region are the chernozem or black soils. No representative of this sub-group has been observed in Colorado, so it is not listed with the sub-groups under pedocal soils in the preceding outline.

DARK BROWN (CHESTNUT COLORED) SOILS.--Soils in this group are characterized by a dark brown, rather thick surface soil. They occur in large areas in the northeastern part of the state, and in smaller discontinuous areas near the range front. This sub-group is represented by several soil series in Colorado, which are synonymous with the best "dry farming" areas in the state.

Keith Series.--The Keith soils occur on the loess-covered nearly level to gently undulating areas in the northeastern part of the state. Probably the largest continuous areas occur south of Wray in the vicinity of Idalia. Very fine sandy loam, silt loam and clay loam types occur in the state. There is little difference between them in agricultural value. They are considered among the best soils in the state for small grain production, as they have deep friable profiles, high water holding capacity, and all of them absorb water rapidly considering their "hardland" textures.

The following is a description of the most western type location of Keith silt loam thus far observed.

T. 4 N., R. 51 W., Sec. 13 - 300 feet E. of N. 1/4 corner. The Keith soils this far west generally occur in nearly level swales, or slightly depressed areas, which favors slightly greater accumulation of soil moisture and grass growth. The above location is in a nearly level slightly depressed swale, where drainage is good but slow.

- 0"-9" Dark grayish-brown friable silt loam with fairly well developed columnar form. This layer is as thick as 12 inches in nearby areas.
- 9"-16" Grayish-brown friable silty clay loam with pronounced columnar breakage and cloddy structure.
- 16"-24" Light grayish-brown to grayish-yellow columnar cloddy silt loam to silty clay loam. This layer is a trifle looser than the one above. It is the upper part of the lime zone and is highly calcareous.
- 24"-36" Very light grayish-yellow floury silt. This is the main part of the lime zone and differs from the layer below it only in its apparently greater accumulation of lime.

Below 36" is light grayish-yellow floury structureless silt (loess) from which the soil developed.

There is a valley phase of the Keith soils that has been recognized. It differs from the typical Keith soils chiefly in its depth of profile. The topsoil is from 15 to 30 inches thick. The soil is dark grayish-brown in the surface and friable throughout. It occurs in the narrow upland valleys which have very slight gradients due to being blocked by sandhills. The water stands on these soils for several hours or perhaps days after floods.

In general, the valley phase receives some moisture by runoff from higher land, and is considered slightly superior to typical Keith as a farm soil.

Rosebud Series.--The soils of this series are developed from loosely indurated, light colored, and limy sandstone of tertiary age. They are on nearly level to gently rolling uplands in the northeastern part of the state.

After Hayes:

These soils are normal or nearly normal in development. The topsoils are grayish-brown to dark grayish-brown and about 8 to 14 inches thick. The surface 1- or 2-inch layer is mulch-like and the remainder has a coarse mealy structure. The more extensive types range in texture from fine sandy loam to silt loam.

The upper layer of the subsoil is grayish-brown and slightly heavier than the topsoil but is very friable. This layer, where well developed, is 12 to 18 inches thick. It merges below with the zone of maximum lime enrichment, which consists of loose, very light grayish-brown or brownish-yellow limy silt to very fine sandy loam.

The subsoil has no definite structure and breaks upon drying into soft angular clods of various sizes and shapes. It has columnar form in the upper part.

The carbonates, in the zone of maximum lime enrichment, are in finely divided form thoroughly mixed with the mineral constituents and in film-like coatings on the surfaces of the clods. Hard lime concretions are few or absent.

The unaltered or only partially weathered sandstone is within a 6-foot depth, even on the more nearly level areas. At places it contains coarse material in the form of water-worn granitic gravel and pebbles, a few of which may occur in any part of the soil section.

The principal features of these soils are the moderately dark topsoils, the lighter colored subsoils with a pronounced zone of lime enrichment, and the limy substratum of Tertiary sandstone.

The Rosebud are very similar to the Tripp soils but have developed on upland areas of Tertiary sandstone in situ, while the associated Tripp are on stream terraces. The Rosebud rest on the same geological formation that underlies the Holt soils but are in a region of lower precipitation and less abundant grass growth than the Holt and have lighter colored topsoils and higher lying zones of carbonate accumulation. They have formed over sandier beds of the Tertiary than the Pullman and Richfield soils of more southern latitudes and are neither as deeply developed nor as heavy as those soils. They lack the heavy layer so characteristic of the subsoils in types of the Dawes and Dunlap series. The Rosebud are much better developed than the shallow and stony to gravelly Canyon soils and differ from the Keith soils in having substrata of Tertiary sandstone instead of loess.

Rosebud soils are developed on parent materials deposited near the same geologic time as are the Larimer, Akron, and Ft. Lyons series. However, the Rosebud has a darker colored surface layer than any of these soils, chiefly because it has developed in a region of more effective precipitation which favored greater accumulation of organic matter.

Tripp Series.--The Tripp soils are developed on some of the nearly level "hardland" terrace situations in northeastern Colorado. They have developed on fine sands, silt and clay that have been deposited from the streams when they were flowing at higher levels. Some of the materials have

been deposited by wind action. The soil profiles are very similar to the Keith soils as they have dark grayish-brown surface soils, 10 to 15 inches in thickness and the lower subsoil or lime zone is encountered at 16 to 24 inches. The substrata may have some gravel and coarse sand in it, but not enough to make it grade coarser than fine sandy loam. No type locations of these soils have been made, and observations indicate that they will occupy a relatively small total area in Colorado.

Tripp soils have a darker colored surface layer than any other "hardland" soils occupying terrace positions in eastern Colorado. Bridgeport soils differ from Tripp soils in having less well developed profiles, usually lighter colored surface layers and a higher lying lime supply.

Orman Series.--The Orman series comprises moderately dark soils that have developed on clayey terrace deposits derived principally from the Pierre formation. These soils are in valleys, chiefly within areas of Pierre and Boyero soils largely in the central eastern and northeastern part of the state. The following paragraphs by Hayes accurately describe the Orman soils in Colorado.

Surface drainage is adequate but slow. There is little or no under-drainage owing to the dense clayey nature of the parent material.

The topsoils, which are 8 to 12 inches thick, are grayish-brown to dark grayish-brown and consist largely of silt, clay, or mixtures of these materials. They show little or no structural development.

The subsoil is light grayish-brown to pale olive, dense, structureless clay.

Stratified limy shales and clays from the Pierre formation are about 3 or more feet beneath the surface. They range from light grayish-brown to almost black, although each stratum is quite uniform in color.

The soils are calcareous below about 8 inches. A zone of carbonate accumulation may occur in any part of the subsoil but is not usually pronounced.

The principal features of these soils are their moderately dark topsoils, their slightly lighter colored, dense, clayey subsoils, and their substrata of water-laid limy shales and clays.

The Orman soils are quite similar to those of the Verdel series which have developed on more easterly terrace deposits of Pierre shales and clays. The verdel are in a region of higher precipitation, more abundant grass growth, and more rapid vegetal decay than the Orman and have much darker topsoils. In addition, the lime has been leached a little deeper, as a rule, and more of it occupies seams and cracks in the Verdel than in the Orman soils.

The soils of this series have much heavier, more clayey, and less deeply developed profiles and more shaly substrata than the Tripp and Yale soils, which are also on stream terraces.

The Orman soils have darker colored surface layers than the Billings soils, which occupy similar positions in regions of lower rainfall. Their profile characteristics are quite similar to the Boyero soils in some places except that the latter occupy upland positions and are generally lighter in color.

The Orman soils are, in general, rather low in agricultural value unless they are under irrigation. Under irrigation, alkali spots develop due to the slow underdrainage and rather high salt content of the soil material. A few areas of the clay loam type have fair value as producers of small grains under "dry land" conditions.

Denova Series.---These soils occupy nearly level to gently rolling areas usually between sandhill and "hardland" soils or in valley-like situations within the sandhills. Their parent material is probably a result of sandhill and hardland soil materials becoming mixed.

In general, the physical characteristics of these soils are nearly ideal for the maximum year after year yields of "dry land" crops, particularly corn. The surface soils are fairly thick, sandy loams to loamy sands that are dark in color, high in nutrients and possess a rapid absorbing rate for moisture but a rather low moisture-holding capacity.

Thus, the surface soils pass a relatively large percentage of the precipitation into the subsoil. The subsoils contain a much higher percentage of clay than the surface soils so they are capable of holding large amounts of water for plant use.

A general description of the sandy loam type as it occurs in north-eastern Washington county follows:

The topsoil to a depth of 10 to 14 inches is dark grayish-brown friable sandy loam with no definite structure. The next layer, which averages 14 to 20 inches thick, differs little in color from the topsoil, but contains a higher percentage of clay and is a dark grayish-brown friable sandy clay. Lime carbonate is encountered at about the 3 foot depth and continues downward. The lower part of the subsoil and substrata vary considerably in texture. They may become either higher or lower in sand content with depth.

The Denova profile must have the following essential characteristics:

A dark grayish-brown sandy loam to loamy sand topsoil, 12 to 30 inches thick.

Lime in the subsoil at about $2\frac{1}{2}$ to 4 feet.

At least $1\frac{1}{2}$ feet of material in the upper 4 feet that has a moderate to high water-holding capacity.

The Denova soils have darker surface layers than the sandier Akron soils, and have a heavier textured limier subsoil and darker colored topsoil than the Otis soils.

Dunlap Series.—The Dunlap series includes areas of dark brown, moderately heavy soils on nearly level to gently undulating table lands in northwestern Nebraska. These soils have developed under a dominantly short grass cover, a low precipitation and good but rather slow surface and sub-surface-drainage, partly in situ from soft Tertiary sandstones but mostly from a thin layer of wind-blown sandy silt deposited on the Tertiary bedrock, probably during late Pleistocene time. They have not been subjected to more than normal erosion, except locally, and are nearly everywhere deeply developed. The topsoils, which range in thickness from 10 to 14 inches, have about the usual amount of organic matter for normal soils of this region and the usual fine crumb structure and thin surface mulch. They are dark grayish-brown and friable throughout. The silt loam texture predominates.

The upper part of the subsoil has received considerable fine mineral material, carried into it by percolating waters, and is moderately heavy but not compact. It has a silty clay loam texture, a well developed prismatic structure and is grayish-brown, usually with a barely perceptible green-olive tinge.

The lower subsoil layer is the zone of maximum lime accumulation. It consists of light gray or almost white floury silt or silt and sand mixture with columnar breakage and an abundance of finely disseminated lime which largely accounts for its light color. This layer begins at a depth of about 30 inches and extends downward 12 to 18 inches where it rests either on the weathered surface of the Tertiary bedrock or on wind-laid deposits overlying the rock.

All horizons of the profile give way gradually, one into another, there being no abrupt change in color, texture, structure or consistence between the different layers. The upper part of the subsoil although heavy has no claypan tendencies. In this respect these soils differ from those of the Dawes series in which there is a sharp line of contact between the topsoil and subsoil.

The Dunlap soils have heavier upper subsoil layers than occur in either the Rosebud or Keith soils. They are somewhat similar to the Yale soils but are on the uplands, whereas the Yale are on stream terraces.

Practically all areas of these soils are cultivated, mainly under dry farming methods. Wheat, corn, rye, and barley, ranking in acreage during most years in about the order named, are grown principally. Irish potatoes are produced for seed in certain localities. The crop yields vary widely with differences in the amount and distribution of the precipitation and in the length of the growing season. All yields are seriously reduced by drought in some years and occasionally corn may fail to mature before its growth is stopped by fall frosts. Over long periods, however, these soils give higher average yields of crops for which they are suited than can be obtained on any other soils of the uplands in the climatic region of their occurrence.

In common with most of the smoother lying hard-land soils of the uplands in western Nebraska, the Dunlap soils are practically devoid of trees except for a few that have been planted near farmsteads. These trees, most of which are ash, have made but slow growth, are short and scrubby and have suffered rather severely from borers. They indicate, however, that low shelterbelts consisting of highly drought resistant tree species, having few insect pests, probably can be established on Dunlap soils in the moister localities. Such shelterbelts should attain sufficient height to protect stock and low farm buildings.

Dawes series.---The Dawes soils are in western Nebraska and north-eastern Colorado in nearly level to gently sloping areas and shallow sags or basins on the less sandy parts of the uplands. They are intrazonal soils of the dark brown soil province where they have developed under the semi-arid climate and short grass cover normal to the region but under subnormal surface- and under-drainage. The parent material is mainly weathered limy sandstones and clays of Tertiary age but in places consists partially of wind-blown silt and sandy silt deposited since Tertiary times. The soils have not been severely eroded by water or wind, except locally.

The topsoils are mostly silty, range from 9 to 15 inches thick, are friable and have a fine crumb structure except in the upper 1-or -2-inch layer which is mulch-like to platy. They have accumulated considerable decomposed grass remains and, in most places, are dark grayish-brown throughout. The lower 2- or 3-inch layer, however, contains at least a sprinkling of gray mineral particles from which the organic matter has been leached. Locally these particles are numerous enough to form a thin gray layer at the base of the topsoil.

The subsoil includes two well developed layers. The upper one begins abruptly beneath the topsoil, contains an abundance of clay, is everywhere heavy, and at most places is a true claypan. This layer is from 5 to 15 inches thick, has either a prismatic or a fine-columnar structure and ranges from brown to very dark grayish-brown or almost black in the upper part but gradually becomes lighter colored with depth. In areas where the columnar structure is best developed small patches occur in which the columns have well rounded tops so characteristic of a degraded solonetz.

The upper part of the subsoil is line-free and is heaviest where it contacts the topsoil. It becomes increasingly calcareous, friable and massive downward and its basal portion contains numerous white splotches and spots in which the lime has concentrated.

The lower subsoil layer is the zone of maximum lime accumulation. It consists of friable silt or very fine sand to which an abundance of finely disseminated lime has given a very light gray or almost white color. This layer rests on the Tertiary beds or on wind-laid silt or sand-silt mixtures, usually within a depth of 4 feet.

The Dawes soils differ from those of the Dunlap series, which they somewhat resemble, in having a more nearly impervious upper subsoil layer, a higher lying zone of lime accumulation and a more abrupt contact between the topsoil and the upper part of the subsoil. They have better drainage and thicker surface layers than the Scott soils with which they may be closely associated. Moreover, they have an abundance of lime all of which has been leached from the Scott. Their topsoils are slightly lighter colored than those of either the Butler or Fillmore soils but are darker, and at most places thicker, than those of the Weld and the Akron¹ soils which have developed from loess and sandstone respectively on well drained uplands in the Brown soil province to the west.

Practically all of the Dawes soils are used for cultivated crops. They are in a region where the precipitation, even when normal, is hardly sufficient for profitable grain yields and most of them are fallowed during alternate years in order to increase the soil moisture supply. Small grains, corn and sorgo are grown chiefly. The yields of small grains, mainly wheat, are not high, except in wet seasons but compare favorably with those obtained

¹Tentative series name

on the best soils of the uplands in the region. The heavy layer in the Dawes soils restricts downward water percolation and limits the crop available moisture largely to the topsoil. Wheat, which matures rather early in the season, usually before the topsoil moisture is exhausted, naturally does better than most late maturing crops. Corn does well in the wetter seasons and gives profitable yields, even during the drier years, if grown in the depressed areas where water from precipitation is supplemented by run-off from higher land. Except in the lower situations, however, corn frequently fails on these soils in seasons of subnormal rainfall. Sorgo, which has the ability to become partially dormant during dry spells gives profitable yields except in seasons characterized by the most prolonged droughts.

The soils of this series are treeless except for a few slow growing and scrubby ash, Chinese elm, hackberry, honey locust and cedar trees which have been planted near dwellings on some of the farms. Low shelterbelts of highly drought resistant trees might be established in the lower basins where run-off from higher levels appreciably increases the moisture supply. The Dawes soils, as a whole, are not sufficiently porous to absorb and carry into their deeper layers enough of the rather low precipitation to support satisfactory tree growth.

Cheyenne Series.—The Cheyenne series includes normally developed soils of gravelly stream terraces and terrace-like colluvial fans or aprons in the northern half of the Dark Brown or Chestnut soil province. These soils occupy discontinuous strips of various widths in some of the river and larger creek valleys throughout western Nebraska and South Dakota, eastern Wyoming, and northeastern Colorado. The terraces, fans, and aprons lie from 10 to more than 60 feet above the present bottomlands and are not subject to overflow from the main streams. They are nearly level to very gently sloping, in most places, although some of the older and higher ones are slightly rolling. Surface-drainage channels are absent or poorly established except where streams, issuing from higher land, cross the terraces.

These soils have developed under the influence of mixed short and prairie grasses, a rather low precipitation, good to excessive under-drainage, and slow vegetal decay. The topsoils, which are generally between 8 and 10 inches thick, have accumulated a moderate supply of organic matter and are dark grayish-brown—the normal color of soils in this region. They are friable and without well defined structure. Most of them are rather coarse but, except locally, contain enough fine material to afford good coherence. The loam texture predominates, although sandy loams and gravelly loams are common.

The upper part of the subsoil is brown to light brown sandy loam or sandy gravelly loam, from 10 to 20 inches thick. This layer is everywhere friable but is variable in gravel content, and consequently porosity. In some places it has good coherence or "body" and is only slightly more open and porous than the topsoil. In other localities it consists largely of gravel with little intersitial material, and is extremely porous.

The lower part of the soil section is a gray, incoherent mixture of coarse sand and gravel. It includes a variety of water-worn fragments from igneous and sedimentary rocks. Quartz, feldspar, and pebbles of granite predominate.

A pronounced zone of lime enrichment begins at a depth ranging, usually, between 24 and 30 inches. In this zone, the carbonates occur both

in finely divided form and as hard coatings on the lower sides of the gravels.

The soils of the Cheyenne series are analogous to those of the Sioux series which have developed from similar parent materials on terraces in the more humid Chemozon region to the east. They have lighter colored--more brownish--and thinner topsoils than the Sioux, however, and, as a rule, have higher lying zones of carbonate accumulation.

The Cheyenne and Gilcrest soils are almost identical except in topsoil color. The Gilcrest soils have developed on gravelly stream terraces but are in the more arid Brown soil province to the west, and have accumulated relatively small amounts of organic matter. Their topsoils are brown instead of dark brown as in the Cheyenne soils.

The soils of the Cheyenne, Tripp, and Bridgeport series are closely associated in many places, but of these, the Cheyenne soils are the only ones having notable amounts of gravel in their subsoils and substrata.

Owing to their high gravel content, all soils of the Cheyenne series absorb water rapidly, but they are unable to hold much moisture in their subsoils and, as a whole, are droughty. Those having the finer textured topsoil and upper subsoil layers are fairly well suited for growing corn and small grains under dry farming methods. In areas where the upper soil layers are coarse, the soils are of little value for cultivated crops, even when watered artificially, unless the water supply is abundant. A part of these soils along Lodgepole Creek, in Kimball County, Nebraska, is used successfully for growing Irish potatoes, alfalfa, sugar beets--and to a less extent, small grains, cabbage, and beans--under irrigation.

Except where supplementary water is available, the suitability of the Cheyenne soils for tree growth is doubtful. Thrifty, though widely scattered, elm, ash, hackberry, and cottonwood trees have become established naturally in some areas of these soils, occupying low terraces, where the roots probably reach the same water table that underlies the adjoining bottomlands. Undoubtedly, more trees can be grown in these and similar areas. Also, it is not unreasonable to expect that trees can be established on the higher terraces, fans, and aprons with little difficulty or expense in localities where it is feasible to utilize the run-off from the uplands. Under irrigation, all of the Cheyenne soils are suitable for tree production.

Yale series.-- The Yale soils are in the northern part of the Dark Brown soil province on light colored calcareous materials, mainly silt and silty clay, of stream terraces or benches. They have been mapped, as yet, only in western Nebraska, chiefly in Box Butte and Sheridan counties. The terraces lie from 8 to 20 feet above the present bottomlands and are not subject to overflow from the main streams. They are so nearly level that run-off is slow and much of the light precipitation sinks into the ground or evaporates. Water does not stand on the land except in a few shallow depressions and here only for short periods.

These soils have rather low infiltration capacities but high water holding powers, and keep much of the absorbed moisture in the upper part of the profile where loss through evaporation is greatest. They have developed under a vegetative cover consisting dominantly of short grasses, and under insufficient moisture to afford rapid vegetal decay. The topsoils, which range in thickness from 8 to 12 inches, have accumulated a moderate supply of organic matter and are dark grayish-brown. They are friable throughout and have the fine-crumbs structure and thin surface mulch so characteristic of well developed

topsoils in this region. The silt loam and very fine sandy loam textures predominate.

The upper part of the subsoil is brown to light brown, heavy, silty clay loam, which in most places, has a pronounced fine-prismatic structure but locally is massive. It contacts the topsoil rather abruptly and, as a rule, is semi-claypan-like in character. This layer ranges between 6 inches and 2 feet in thickness and rests on grayish-white, floury silt or silty clay loam having a well developed zone of carbonate accumulation. The parent terrace deposits are within a depth of 4 feet.

The Yale differ from the Tripp soils mainly in having a more clayey and much heavier upper subsoil layer, probably caused by slower surface drainage and greater downward leaching of fine material from the topsoil. They also have slightly higher lying zones of carbonate accumulation than occur in the Tripp.

Nearly all of these soils are dry farmed and used mainly for growing small grains, though Irish potatoes are produced commercially in some localities. Crop yields during average years are a little lower than on the Tripp soils and in unusually dry seasons may be lower than on the best soils of the uplands. The heavy upper subsoil layer in the Yale types checks water penetration and most of the moisture, available to plants, is held in the topsoil. During wet years crops yield as high as on any land in the region. Practically all of these soils lay well for irrigation but most of them, yet mapped, are along streams too small to supply much water.

No wilding trees are growing in areas of Yale soils although some of the green ash still survive which were planted during the late seventies under the timber culture acts. These plantings received little care except possibly during the first few years. The trees grow slowly and only a few attained heights exceeding 20 feet. Most of them are now dead or dying. They have proved, however, that shelterbelts consisting of highly drought resistant trees can be established on the Yale soils, and if carefully managed will become high enough to afford considerable protection for stock and farm buildings.

BROWN SOILS.--The brown soils in Colorado develop under a mean annual precipitation of about $13\frac{1}{2}$ to 17 inches and a mean annual temperature of about 45° to 55° F.

These soils have friable surface and subsoils, and differ from the dark brown soils only in color of surface soil and depth of profile. Their lighter color is due to less grass growth and decay, hence, a lower percentage of organic matter in the surface soil. Line zones occur at somewhat shallower depths in the brown than in the dark brown soils.

The brown soils occupy extensive areas throughout most of eastern Colorado, and represent areas wherein a very careful system of farming is necessary to produce field crops at a profit.

Larimer Series.--The Larimer soils have developed on tertiary deposits of gravel, fine sands and clay with a moderate to very high lime content. They generally occupy nearly level to gently rolling areas throughout eastern Colorado, north of the Arkansas River.

Near the mountains there is considerable variation in the mean annual temperature and precipitation within short distances, and in this vicinity small areas of the soils have been mapped that have dark enough surface soils to be included in the dark brown soil group. In general, however, these soils have brown or grayish-brown surface soils and definitely belong in the brown soil group.

The surface soils are chiefly loam, very fine sandy loam or fine sandy loam, grayish-brown or somewhat reddish-brown in color, coarsely cloddy, or structureless, and 6 to 15 inches thick. They are non-calcareous and usually contain a rather high percentage of small granitic gravel which is usually angular.

The subsoils are light brown or light reddish-brown loams to clay loams, 6 to 15 inches thick. They break into large irregular clods and rarely show a strong columnar breakage. This layer is usually calcareous, and often very high in lime carbonate, particularly in the lower part.

The substrata are reddish-brown or light grayish-brown, highly calcareous and sometimes slightly micaceous gravelly sands and gravelly loams of tertiary age.

The Larimer soils do not have as dark colored surface soils and their profiles (within the same textural grade on similar slopes) have not developed as deeply as have the Rosebud soils, although both soil series have developed on parent materials which are probably the same general age.

The Akron soils (although developed on similar parent materials) have a semi-claypan subsoil of variable compaction and thickness whereas the Larimer soils are friable throughout. The Larimer series have developed under a higher rainfall than the Ft. Lyons series and thus have darker colored surface soils and surface layers of several inches that have been leached of lime carbonate. The Ft. Lyons soils are calcareous from the surface downward.

The Baca soils are quite similar to the Larimer soils in profile development. The major difference seems to be that the parent materials of the Larimer are high in gravel and sand content, while the Baca parent materials are high in silt and low in gravel and sand content. Both parent materials are considered geologically as tertiary deposits. Further the Baca soils are generally developed in more southern latitudes and may be considered as belonging in the southern brown soil group.

Baca Series.--The Baca soils are developed on tertiary materials which are rather fine grained. They contain some gravel, but this constituent is only present as a scattering throughout the parent material. Large areas of these soils occupy nearly level to undulating areas in southeastern Colorado and southwestern Kansas.

The surface soils are brown or grayish-brown faintly granular to structureless, very fine sandy loams to clay loams, 4 to 8 inches thick. The upper subsoils to a depth of 15 inches may be light brown non-calcareous, and slightly heavier than the surface soils. They have a cloddy structure. The lower subsoils are highly calcareous loams or clay loams, very light grayish-brown in color.

In many places the upper subsoil is absent and 4 to 8 inches of brown surface soil rests directly on highly calcareous very light grayish- or pinkish-brown loam or clay loam which is quite uniform to depths of 5 feet or more.

The Baca soils have lighter colored surface soils and shallower depths to lime than do the Richfield soils. The parent material and entire soil profiles of the Larimer soils contain more gravel than do the Baca soils, otherwise these two soils are quite similar.

The Ft. Lyons soils are shallower to lime and have lighter colored surface soils than the Baca series.

The Colby and Baca soils are quite similar in all profile characteristics but the Colby is developed on loess and the Baca on fine grained tertiary parent materials.

Colby Series.---The Colby soils have developed on nearly level to gently rolling topography and on loess parent materials. The loess in Colorado varies in thickness from a few inches to over 50 feet. Over wide areas it is 10 to 15 feet thick.

In virgin locations the surface one to two inches of these soils may be light brown in color and faintly calcareous. In general, however, the upper 6 to 10 inches of the soils are brown structureless or faintly and finely granular very fine sandy loam, silt loam, clay loam or loam. Immediately below the surface soil is the lime zone, which is 6 to 10 inches thick, and differs very little from the underlying parent material except that there are a few more soft segregation of lime. In many places the subsoil to a depth of 20 inches has a weakly developed cloddy structure. Otherwise the profile may well be considered structureless throughout. The parent material is very light brown or yellowish-brown limy fine grained loess. Everywhere these soils are remarkably free of gravel. However, an occasional gravel fragment or particle found in the soil or substrata does not eliminate the soil from this series even though we cannot explain the presence of these gravel fragments.

The Colby soils are lighter in color and leached of lime carbonate to a shallower depth than the Keith soils. The Colby soils have a surface layer of several inches that is leached of lime carbonate, and the Prowers soils are limy from the surface downward. Furthermore the Colby surface soils are brown and the Prowers surface soils are very light brown or gray. The Colby profile is friable throughout and that of the Weld soils contains a semi-claypan or solonchic development in the subsoil. The Keith, Colby, Prowers, and Weld series are all developed on loess.

The Colby and Larimer soils have about the same profile development (on similar slope and texture of parent materials) but the Larimer soils are developed on tertiary deposits.

Terry Series.---The Terry soils have developed on level to gently rolling topography, and on soft fine grained sandstone, and mixed sandstone and shale formations. The largest known areas of the soil occur in the northern part of Colorado and are developed on sandstone layers within the Pierre and Laramie formations. These soils often occur in association with those developed on clay shales.

Near the mountains there is considerable variation in the mean annual temperature and precipitation within short distances and in this vicinity small areas of the Terry soils have been mapped that have dark enough surface soils to be included in the dark brown soil group. In general, however, the Terry soils have brown to olive-brown surface soils and definitely belong in the brown soil group. A description of Terry fine sandy loam as observed 900 feet north of the southeast corner of Sec. 25, T. 8 N., R. 69 W., follows: (Virgin roadside cut on a slope of about 5%)

- 0"-2" Brown, structureless, calcareous fine sandy loam.
- 2"-8" Brown, structureless, non-calcareous fine sandy loam.
- 8"-15" Light brown calcareous structureless fine sandy loam containing numerous crust-like fragments of rusty-brown sandstone.
- 15"-30" Very light brown calcareous partially disintegrated soft sandstone.
- 30- Soft sandstone which may have been affected by soil weathering but apparently has not lost its original color or form.

The finer textured types of the Terry soils have been developed on mixed sandstone and shale beds.

The Terry soils generally have more of an olive brown tinge to the entire profile than the Larimer soils, and the Terry soils are developed on sandstone and shale while the Larimer are developed on tertiary materials.

Berthoud Series.--The Berthoud soils occupy colluvial outwash areas of nearly level to rolling topography along the foothills in northern Colorado. They have developed chiefly on fine textured calcareous materials containing scattering of thin limestone fragments. The deposits are old enough in most places for the soil to have developed a profile which approaches that typical for the region.

The surface soil is brown to dark brown, 6 to 12 inches thick, and usually only faintly calcareous. A cultivated field presents a mottled dark and light brown appearance indicating the variable color and thickness of the surface soil.

The subsoils are fine grained (loam or clay loam) light brown calcareous colluvial mixtures which are not separable from the soils' parent material.

The Berthoud soils are quite similar to the Minnequa soils, but have darker colored surface soils. They have profiles much like the Colby and Ft. Collins but occupy high colluvial slopes whereas the former is on uplands and the latter on stream terraces.

Capulin Series.--The Capulin soils have developed on nearly level to gently rolling topography, and on volcanic basalt. The largest continuous areas that have been observed in Colorado occur on Mesa de Maya on south-eastern Las Animas County. On this mesa the surface soils are brown to dark brown loams or clay loams, 8 to 14 inches thick, underlain by a mixture of light brown clay loam and partially decomposed basaltic lava 1 to 3 feet thick. The unmodified basalt could not be exposed in a pit. This is the only soil series in Colorado that has been recognized as being residual on basaltic lava. However, there are indications that soils may be developed on similar materials in the western part of the state.

Rhyolite Series.--These soils have developed on fine textured deposits developed on rhyolite beds. They occupy nearly level to rolling situations and have been observed only in the higher elevations free of

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in diameter. The columnar material breaks naturally into aggregates of irregular lengths up to $1\frac{1}{2}$ inches and of more or less prismatic shape. All of the aggregates are coated with a dark brown to dark reddish-brown colloidal film. This is the heaviest layer of the profile.

21" Below 21 inches the profile loses most of its columnar form and the material becomes a rather massive grayish-brown to light grayish-brown clay loam of considerably looser consistency than the overlying layer. It is highly calcareous, the lime being in disseminated form and in mycelium-like threads which follow rootlet cavities. At a depth of about 4 feet is light grayish-brown fine sandy loam containing a few small gravel.

The parent material beginning at the 5-foot depth is a bluish-white gravelly sand with sufficient clay to give it moderate coherence. It is thought to be either the Castle Rock or the Dawson formation in this particular profile although part of it may be from the Rhyolite bed. It is quite calcareous, however, and neither the Castle Rock, Rhyolite, nor Dawson is known to contain lime.

The Rhyolite soils differ from the Limon series in the appearance of the subsoil. The Limon subsoils are more definitely columnar, consist of more highly dispersed clays, and usually contain more lime in the lower subsoils. The Rhyolite soils are more porous below 4 feet than are the Limon soils. The entire soil profile of the Rhyolite soils is probably higher in clay than that of any other of the brown soils except those developing from clay shale materials.

Ordway Series.--These soils have developed on nearly level to undulating topography from orange brown gypsiferous clay shale containing thin sand layers, and chalk rock mixtures. They are mainly in regions of 12 to 14 inches of mean annual precipitation, and owe their color more to the parent material color than to the accumulation of organic material in the surface soil. In general, they are clay loams and clays, high in salt content, chiefly lime carbonate and gypsum. Under irrigation they rapidly develop alkali spots. Nearly all unirrigated areas are in native pasture.

The surface soils vary from 2 to 8 inches in depth. They are nearly the same color as the underlying material, but may be slightly darker and more finely granular. They are limy from the surface downward. The subsoils are 10 to 48 inches thick, cloddy, and very high in clay, gypsum, and lime. They usually contain a scattering of coarse sand and fine gravel.

The parent shale contains seams or thin layers of gypsum, coarse sand, and gravel or calcium carbonate in many places.

If the soil is formed in "situ" it is difficult to explain why it is weathered so deeply in some places. Perhaps these deeper areas owe a part of their depth to transportation of materials from closely surrounding areas.

The Ordway series, especially the shallower phases, differ from the Pierre chiefly in the mixed characters of the parent material, and its

more yellowish or orange-brown color. The shallow phase of the Ordway clay might be combined with the Pierre if Pierre is to be retained as an immature soil on clay shales. The more deeply developed Ordway soils will not fit in the Pierre series. They differ from the Hugo series in being lighter colored throughout. The Ordway soils have yellowish brown to gray surface soils and Hugo surface soils are dark brown to brown.

Otero Series.--These soils occur on the low lying uplands that merge with the terraces on both sides of Arkansas River. They are apparently developed on interbedded reworked sand and clay.

The surface soils are grayish-brown and 6 to 12 inches thick. They are usually calcareous throughout in the heavier textures but may be very low in lime in the more sandy textures.

The subsoil is 8 to 20 inches thick and orange-brown in color. It is highly calcareous and a mixture of sand and clay which in general produce a loam subsoil.

The substratum is interbedded brown, yellow-brown and grayish-brown sand and clay. Apparently this material has been deposited by water with very little wind action. It does not seem to be residual as no rock is encountered to a depth of 9 feet or more.

In general, the Otero has been derived from coarser, more recently deposited parent materials than have the Ordway soils. Both of these series have an orange-brown tinge throughout their profiles.

Ft. Collins Series.---The Ft. Collins soils are developed on stream terraces chiefly along the South Platte River and its tributaries. They have developed on fine textured (very fine sandy loam or finer) alluvial deposits, which contain no more than a scattering of gravel.

The surface soils are 10 to 14 inches thick and generally structureless. They are brown or slightly reddish-brown in color. The lower part of the surface soil or the upper subsoil may be considerably heavier in texture and tend toward columnar form in some places. No doubt, these local spots of semi-claypan subsoil types should be included in a new series, but in completed surveys they occupy a relatively small area and have been included with the Ft. Collins series.

The subsoils are light pinkish-brown or light yellowish-brown, very fine sandy loam or clay loams. They are quite high in lime which occurs chiefly as soft segregations and in disseminated form throughout the layer.

The substratum is usually slightly lighter in texture than the subsoil and contains very few or no lime segregations but often has a scattering of fine gravel. Otherwise the subsoil and substratum do not differ.

Lime carbonate does not usually occur in the surface soil, but in some places particularly where several inches of the surface have been eroded away, the soil is calcareous from the surface downward.

The Ft. Collins series has profile characteristics very similar to the Colby soils, but the latter occurs on the upland and is practically free of any gravel. The former is on terraces. The Ft. Collins, Greeley and Gilcrest series have similar profile characteristics and topographic position, but differ in the character of material they are developed on. The Ft. Collins is developed on fine textured deposits, the Greeley on sandy loam or sand deposits, and the Gilcrest on gravelly loam or gravelly sandy loam deposits.

The Rocky Ford series is on terraces and has developed from fine textured materials, but has a lighter colored and more limy surface soil than occurs in the Ft. Collins soils. The Ft. Collins soils have lighter colored and thinner surface soils and are not leached of lime to as great a depth as the Tripp soils, which they closely resemble otherwise.

Greeley Series.--These soils occur on stream terraces chiefly in northern Colorado. They are developed on sandy or sandy loam alluvial deposits which contain varying but not a high percentage of gravel. In many areas the upper 5 feet of the soil is practically free of gravel.

The surface soils are usually one of the sandy loams and 10 to 20 inches thick. They are brown in color, structureless, and generally do not effervesce with hydrochloric acid. The subsoils ordinarily contain somewhat more clay than the surface soils, are lighter in color and are 10 to 15 inches thick. They usually are calcareous. The substratum is always calcareous, and may be chiefly fine sand, gravelly sandy loam, or gravelly loam.

The Greeley series has a higher percentage of sand and often more gravel in the substratum than the Ft. Collins soils, otherwise the two soils are quite similar. The Gilcrest soils contain more gravel throughout but especially more in the substratum than occurs in the corresponding layer of the Greeley soils. Their profiles and topographic positions are similar. The Koen soils, where occurring on terraces, have lighter colored surface soils and lime nearer their surfaces than do the soils of the Greeley series.

Gilcrest Series.--The Gilcrest soils are on stream terraces and are developed on quite gravelly materials.

The surface soils are brown, usually non-calcareous, 6 to 12 inches deep, and sandy loams or gravelly sandy loams. They are usually structureless or faintly cloddy and often have a tinge of orange-brown color.

The subsoils are light brown and rather low in lime, although they will nearly everywhere effervesce, at least slightly, with hydrochloric acid. They are quite high in gravel content usually, but nearly pure gravel does not occur as a rule above the 3 foot depth. The substratum is a gravelly loam to almost pure quartzitic sand with rather small gravel.

In addition to the variable amount of gravel throughout the Gilcrest soils, they are variable in other respects. In local spots they contain considerable clay and have a somewhat granular structure in the subsoil. The lime content varies from barely perceptible to abundant in the upper 30 inches.

The subsoils of the Nunn soils average thicker, darker colored and heavier than those of the Gilcrest soils. In all other characteristics these soils are quite similar.

The Greeley series have less gravel in the profile, particularly in the substratum, than the Gilcrest soils, and the Larimer soils differ from the Gilcrest chiefly in topographic position. Larimer occurs on the upland and Gilcrest on stream terraces.

BROWN SOILS WITH SEMI-CLAYPAN SUBSOILS (SOLONETZIC).—Throughout the central-eastern and other parts of Colorado are many areas of brown soils that have for some reason developed subsoils that are quite high in clay, have a granular structure and columnar or prismatic form. The subsoils are quite similar in some respects to those of the "solonetz" soils of Minnesota, the Dakotas and Nebraska. For this reason, they might be called the "solonetzic" brown soils.

The place in a soil classification scheme for these soils is not clear cut. In some areas, chiefly on loess, the group is continuous on gently sloping as well as nearly level topography. In others, chiefly on the tertiary deposits, the soil is of irregular development and might even be considered as a microphase. In still others, a knowledge of the micro-distribution of the soils would be necessary to show the variability of these soils in very short distances. We might consider this group of soils, as a subgroup of the brown soils, as a group of equal value in the classification scheme as the brown soils, or as a group of intrazonal soils. The first procedure is followed here which may or may not be found most desirable upon further study.

A few soil series have been recognized in Colorado as necessarily belonging in this group of "solonetzic" soils. They occur in a region which varies in precipitation from 14 inches to 17 inches per annum, and mean annual temperatures vary from about 48° F. to 52° F.

These series are associated with both the dark brown and brown soils, but seem in general to require an effective precipitation somewhat between that used to develop the brown and dark brown soils. In many areas, however, the effective moisture cannot be differentiated between that necessary to form "solonetzic" and that necessary to form either brown or dark brown soils. Perhaps further study will show that the salts in the soils have an important bearing on the development of soil profile characteristics in this region.

Akron Series.—This series was tentatively called Burdett at first, but since it is the soil that is quite typically developed on the Akron Experiment Station, the name Akron is suggested as meaning more to those engaged in agricultural research and extension in this region.

The Akron soils in most areas of their occurrence are an association of several quite different soils so thoroughly mixed that only a map showing micro-distribution would indicate the different soils included with this soil series.

These soils are developed on sand, gravel, lime and clay of tertiary age. They occupy gently undulating to gently rolling areas, chiefly in

the northeastern and central eastern part of the state.

The surface soils are 5 to 10 inches thick, brown in color, structureless or weakly cloddy and sandy loam to clay loam in texture.

The subsoils are extremely variable, and are responsible for the necessity of this soil series being an association of a group of series. Below the surface soils is a 5 to 10 inch layer of light brown calcareous loam subsoil, or a 10 to 20 inch layer of reddish-brown blocky clay loam subsoil, or dark grayish-brown to nearly black granular clay to clay loam 10 to 20 inches thick, or a columnar brown solonetz layer 10 to 15 inches thick. In all cases the lower 5 to 10 inches of the subsoil is calcareous.

The subsoils rest on limy gravelly loam or sandy loam in most places, but the content of gravel is quite variable. The entire profile has variable quantities of gravel in it. The substratum in some places is limy sandstone, but indurated substratum is not common except in very small areas.

The Akron series is developed on about the same substrata as the Rosebud series, but has a lighter (browner) surface soil and more variable subsoil. The Akron soils include microphases that are identical to the Larimer, and Baca series, but these latter series do not have the variable usually semi-claypan subsoil that is characteristic of the Akron series. The Akron soils are somewhat more variable than the Weld soils, and also are developed on tertiary materials while the Weld series is developed on loess. Both, however, are characterized by brown surface soils and semi-claypan subsoils.

Weld Series.--The Weld soils generally occupy nearly level to gently undulating situations, but they also occur on rolling topography in some places. They are developed on loess which is a uniform deposit of very fine sand, silt, and clay, usually less than 20 feet thick in Colorado.

The following description of a profile of the Weld loam by F. A. Hayes is of an average exposure of the series in central-eastern Colorado:

Location - T. 2 N., R. 64 W., Sec. 27. 500 ft. E. of NW corner.
Roadside cut. Virgin - $2\frac{1}{2}\%$ slope - buffalo grass.

- 0"- $4\frac{1}{2}$ " Very light grayish brown friable silt loam. The upper 2 inches is almost structureless and the remainder has an unusually well developed laminated structure.
- $4\frac{1}{2}$ "- $7\frac{1}{2}$ " Light grayish-brown very slightly compact very fine sandy loam, columnar. This layer represents the basal part of the zone of degradation overlying the solonetz claypan.
- $7\frac{1}{2}$ "-17" Light brown finely columnar clay loam. The columns break into hard irregularly angular although somewhat prismatic aggregates $\frac{1}{8}$ to about $\frac{3}{8}$ inches through. These can scarcely be crushed between finger and thumb. Some of the columns have slightly rounded heads, but there is apparently no degradation between the columns. The upper part of the layer is slightly darker and a trifle

heavier than the lower part, but the difference is scarcely noticeable.

17ⁿ-32ⁿ Light grayish-brown moderately compact silty clay loam but with a pronounced nutlike structure. This layer contains numerous soft segregations of lime and also an abundance of disseminated lime. It is the typical zone of lime accumulation below solonetz layers.

Below 32 inches is light grayish to yellowish brown floury silt of the parent loess. This material is highly calcareous but shows no spots in which the carbonates are segregated.

The profile of the Weld, contrary to that of most solonetz or solonetzic soils, is quite uniform over large areas.

The Akron series has small local areas that are quite similar to the Weld, but the Weld has a much more uniform profile development than does the Akron. The Akron is developed on tertiary materials and the Weld is developed on loess. The Weld series have lighter (brown) surface soils than the Keith series, and also a tighter or more claypan-like subsoil. The Weld and Colby series have the same parent material and surface soil color but the Colby has a more friable subsoil.

Limon Series.---These soils occupy nearly level to gently rolling situations. In many places virgin areas are characterized by numerous shallow depressions 8 to 20 feet in diameter and usually less than one foot in depth. They give the areas a "pock-marked" appearance. The soils are developed on fine textured and often wind deposited materials. The parent materials are clay loams, sandy clay, or clay.

The origin of the wind deposited parent materials appears in many places to be partially from clay shale and fine tertiary material mixed.

Surface soils of this series are 2 to 6 inches thick. They are brown or grayish-brown and usually silty clay loam, clay loam or clay. Their high clay content produces a cloddy structure.

The subsoils consist of 10 to 15 inches of columnar, granular heavy clay, which is hard and brittle when dry and plastic or sticky when wet. The color varies from a light brown or reddish-brown in some to nearly black in other spots. The subsoil varies in color and thickness within very short distances, especially where the small depressions occur. The subsoil in the small depressions usually has quite typical solonetz structure. The surface soil is brown in the upper part and the upper part of the subsoil columns are rounded and covered with a very thin layer of almost white silt and very fine sand. Lime occurs in the lower few inches of the subsoil.

The substratum of this soil is quite variable. It may be a fine textured loess, Ogallala sandstone, fine grained Dawson materials, or a mixture of these materials. In any case, the soil proper (upper 30 inches) is developed on fine uniform textured material.

This series may need to be subdivided upon further study.

The Limon soils have thicker, heavier, more impervious subsoils than either the Weld or Akron series. They have lighter (brownier) surface soils than the Dunlap series and thinner subsoils. The Boyero soils do not have as variable substrata as do the Limon soils.

Boyero Series.--The soils of this series have developed from rather deeply weathered or reworked clay shale parent material. In most places the surface 2 feet show evidence of accumulation either by wind or colluvial action. They occupy rolling to hilly situations generally, although some areas are on nearly level topography.

These soils have clay loam, silty clay loam or clay surface soils, which are grayish-brown to brown in color, and 8 to 30 inches thick. The pronounced thickness in most cases is probably due more to accumulation than to soil development.

The subsoils are lighter in color than the surface soils although the lower part of the surface soil may be darker than the upper part. They are from 10 to 40 inches in thickness and a calcareous massive clay with scattered shale fragments, seams of gypsum and other salts throughout the layer in most places. The substratum is usually clay shale but often is not reached at 6 feet.

These soils might be considered modified phases and colluvial phases of the Pierre soils. However, since Pierre soils rest on clay shales at shallower depths and rather extensive areas of the Boyero soils have been observed, it seems logical that they should carry a separate series name.

The Boyero series occur chiefly in the brown soil localities, but may occur in light brown localities as the soil color is usually due to the color of the parent materials. The Boyero soils are midway between the Pierre and Colby series in agricultural value. They are almost as good as the latter as pasture, but are too high in clay content to produce the ordinary farm crops with as good results as lighter soils.

Nunn Series.--The Nunn soils are developed on nearly level or gently undulating stream terraces in northern Colorado. They have formed on quite gravelly clay loam, alluvial and colluvial deposits.

The surface soils are brown structureless or cloddy gravelly sandy loams to clay loams 4 to 8 inches thick. They are usually noncalcareous.

The upper subsoils consist of 2 to 12 inches of brown or dark brown gravelly material much higher in clay than the surface soils. The lower subsoils are light brown gravelly calcareous sandy loam to clay loam. They vary in thickness from 8 to 15 inches, and constitute the lime zone. However, the lower subsoil and substratum are almost identical so their thickness is not important.

These soils are quite variable within small areas. The chief variation is in the depth and compaction of the subsoil.

The Nunn series and Akron series are quite similar, but the Akron is developed on upland situations and the Nunn on stream terraces. The Nunn soils differ from the Gilcrest only in their heavier claypan-like sub-soil development.

LIGHT BROWN SOILS.---Soils in and bordering the Arkansas River Valley in eastern Colorado and locally in western Colorado have developed under a few inches less annual precipitation and considerably higher evaporation than in other parts of the region. In addition, smaller amounts of the precipitation are in the form of snow and a higher percentage as torrential rains. These climatic factors have produced very little soil leaching, slow plant growth and little organic matter accumulation; hence, a surface soil color, texture, and physical properties that differ little from the sub-soil and substrata.

These soils are, in general, light brown to gray in color (depending on the color of the parent materials) and are calcareous from the surface downward. Their surface soils are consistently lighter colored than any of the soils in the "brown soil" group, and are inferior to the brown soils for the production of field crops and pasture without irrigation. These soils are apparently quite high in nutrient salts and respond well to irrigation. Very few, if any, areas of them are successfully used for farm crops without irrigation.

Ft. Lyons Series.---Light Brown soils that have developed on tertiary sands, gravel, clay, and lime mixtures are included in the Ft. Lyons series. They are on nearly level to gently rolling topography.

The surface soils are 4 to 6 inches thick, structureless and light grayish-brown in color. In virgin areas the upper 1 to 2 inches has been shifted about and is slightly lighter colored than the next few inches.

The subsoil and substratum are highly calcareous sandy loam, loam or clay loam, usually very light grayish-brown in color with varying amounts of waterworn gravel. The profile is calcareous from the surface downward.

The Baca soils have a thicker, browner topsoil than the Ft. Lyons series, and also are usually free of lime carbonate in the upper few inches. Otherwise they are quite similar. The Larimer series has deeper darker topsoils and generally contain a more gravelly substratum than the Ft. Lyons soils. The Ft. Lyons might be considered the gray semi-desert equivalent of the Richfield series (dark brown group).

Prowers Series.---Soils developed on loess parent materials along the Arkansas valley are included with the Prowers series. They occupy nearly level to gently rolling topography, and are typical in all characteristics of "hardland" soils of this part of the state. These soils support a rather sparse growth of short grasses.

The surface soils are light grayish-brown or gray structureless very fine sandy loams to clay loams 3 to 5 inches thick. The color is only slightly darker than the underlying material, and the soil is usually calcareous from the surface down. Occasionally between the depths of about $1\frac{1}{2}$ to 3 inches the soil effervesces only very slightly when dilute hydrochloric acid is applied.

The subsoils are very light brown cloddy or faintly nutlike very fine sandy loams to clay loams. Lime is abundant and may occur entirely disseminated in the mineral soil particles, or partially as numerous soft white segregations. The subsoils are 8 to 20 inches thick.

The parent material or substratum is identical to the subsoil except it is structureless and contains only an occasional lime segregation.

The Prowers soils have thinner lighter colored topsoils than the Colby soils, otherwise they are quite similar.

Prowers, Ft. Lyons, Minnequa and Penrose soils differ chiefly in the parent materials from which they are derived. Prowers is the only one of the group developed on loess.

The Rocky Ford series are quite similar to the Prowers series in profile characteristics. The Rocky Ford is developed on stream terraces, chiefly from stream alluvium, while Prowers is an upland series on loess.

Penrose Series.--The Penrose soils are developed in place from, or at least underlain by limestone, and limy shale of the Benton formations. It occupies nearly level to gently rolling topography chiefly in the western part of the Arkansas Valley region.

The surface soils are 3 to 5 inches thick, light grayish-brown in color, and highly calcareous. They are structureless and very fine sandy loam to clay loam in texture. They may contain a scattering of limestone and shale fragments.

The subsoils are very fine sandy loam to clay in a few places. They have a weak to strong cloddy structure, are very light grayish-brown, usually contain many limestone and shale fragments.

The substratum is platy limestone, limy shale or a mixture of the two.

The Penrose soils differ little from the other "hardland" Sierozem soils in Colorado except that they are residual on older parent materials. No "brown" or "dark brown" soils have been observed in Colorado developed on parent materials similar to those underlying the Penrose series.

Minnequa series.--Throughout the western part of the Arkansas Valley are extensive areas of "hardland" soils developed on materials washed and blown from limestones, shales, and tertiary sands and gravel. These soils have been mapped as the Minnequa series.

The surface soils are fine sandy loams to clay loams, light grayish-brown in color, structureless, calcareous, and 3 to 5 inches thick. The subsoils are sandy loams to clay loams, very light brown, cloddy, and 10 to 25 inches thick. The substratum is a mixture of limestone and shale fragments, gravel, silt, clay, and sand. It is usually loam or heavier in texture. A scattering of limestone and shale fragments, and gravel is common throughout the soil profiles.

The Minnequa series is closely related to the Penrose series. The characteristics of the solum of both soils are quite similar. However, the Penrose is developed on limestone and shale in place, while the Minnequa is developed on transported materials, originating chiefly from limestone and shale. No "dark brown" or "brown" soils have been observed in Colorado developed on parent materials similar to those on which the Minnequa soils have developed.

Billings Series.--These soils have developed on alluvial terraces and high outwash terraces near the foothills along the western part of the Arkansas Valley region. They occupy nearly level areas chiefly, and are developed on wind and water deposited light colored clays.

The surface soils are 2 to 4 inches thick, light brown in color, granular to finely nutlike when dry, calcareous, and light or heavy clays in texture. The subsoils consist of 10 to 30 inches of very light brown highly calcareous cloddy to nutlike clay. The substratum is similar to the subsoil in most places. In some places limy clay shale occurs at 3 to 6 feet below the surface.

The Billings soils differ from the Orman series chiefly in the lighter color of the entire profile. The Rocky Ford soils are not as heavy (high in clay content) in any part of the profile as are the Billings soils.

A large percentage of the Billings soils is under irrigation.

Rocky Ford Series.--The Rocky Ford soils occur on nearly level to gently undulating terraces. They have developed on fine grained (fine sand to loam) stream alluvium, which is high in lime and mineral nutrients and contains a scattering of small gravel in some places.

The surface 3 to 5 inch layer of the Rocky Ford soils is light grayish-brown faintly to strongly calcareous structureless sandy loam to clay loam. The remainder of the soil is very light brown, highly calcareous fine sand to loam. The subsoil may or may not be cloddy in the upper 10 to 20 inches. Except for the faint structure of the subsoil in some places the substratum and subsoil appear almost identical.

The Rocky Ford soils are quite similar to the Ft. Collins soils in topographic position and parent materials. However, the surface soils of the Rocky Ford series are lighter in color, and generally contain more lime.

Intrazonal Soils

Intrazonal soils in eastern Colorado are developed on materials that do not allow a normal impression of the climate - chiefly sand, or on materials so recently deposited that sufficient time has not elapsed for them to develop a normal profile or in shallow depressions or on slopes so steep that surface soils are removed by surface runoff as rapidly as they develop.

Certain parts of the "hardland" plains on nearly level topography may have been eroded by wind to such an extent that they have not developed zonal soils. However, it is assumed that these nearly level areas have developed zonal soils as this is the general consideration, and has not been

proven untrue on any large area of virgin soils in eastern Colorado.

The intrazonal soils will then include sandy soils, soils on recent colluvial deposits, soils on first bottoms, those occurring in intermittent lakes or depressions, and the shallow, eroded, and rolling or steep phases of nearly all of the series occurring on nearly level land as well as the series that are always thin over bedrock and on slopes.

Many intrazonal soils in Colorado occur only in a specific zone. That is, some occur only in the zone giving rise to brown soils while others occur only in the light brown zone. Due to the more or less zonal occurrence of some of these soils, they have been divided into four groups as follows: dark brown zone, dark brown or brown zone, light brown zone, and non-zonal. Another group might be "the phases of zonal soils that are intrazonal in soil characteristics" (shallow, eroded, steep phases). However, we will dismiss this important group by simply stating that they do occur, and phase designations indicate the essential manner in which they differ from the typical zonal series.

DARK BROWN ZONE.--There is only one soil series observed thus far in Colorado that occurs only in the zone giving rise to dark brown soils, and which is intrazonal in soil characteristics. Its description follows:

Table Mountain Series.--These soils have been recognized along the foothills in the vicinity of Golden. They occur in small irregular belts at the base of steep slopes. The soils are simply colluvial deposits of dark brown to very dark brown, usually non-calcareous, more or less structureless, sandy loam to clay loam, 3 or more feet thick. The deposits contain varying quantities of sandstone and shale fragments as well as fragments of crystalline rocks and gravel.

This series differs from the Judson series of central Nebraska only in the character of parent material. The Judson soils do not have the rock fragments in them that are common in the Table Mountain soils. The Judson soils average somewhat darker in color than the Table Mountains soils also. The Bridgeport soils are higher in lime content, lighter in color, and contain less rock fragments than the Table Mountain series.

DARK BROWN OR BROWN ZONE.--The intrazonal soils occurring only in these zones in Colorado are of three types, sandy, young colluvial, and young due to continual erosion.

Arapahoe Series.--The Arapahoe soils are developed in broad gently sloping swales. They receive some supplemental moisture in the form of runoff from higher levels, which has produced a stage of soil development similar to that which normally occurs in regions of considerably higher mean annual precipitation than occurs over most of eastern Colorado.

The surface soils are about a foot thick and dark brown to nearly black in color. Silt loam and silty clay loam textures predominate. The upper subsoils are brown to nearly black clays, 12 to 20 inches thick, and of a columnar form and granular structure. The lower subsoils are light brown to brown calcareous silt loams or clay loams. The substrata are loess or fine textured tertiary materials.

Due to the mode of formation of this soil series considerable variation must be allowed in its profile characteristics.

The Arapahoe soils have thicker darker colored surface soils than any of the brown soils in eastern Colorado. The Rosebud and Keith surface soils may be as dark colored and thick as the Arapahoe soils, but their subsoils are more friable.

In western Nebraska many areas of soils similar to the Arapahoe series were correlated as a deep phase of Keith silt loam. However, most of these deep phase areas have more friable subsoils than do the Arapahoe soils. The Dawes soils are quite similar to the Arapahoe soils in many profile characteristics, but are developed on Ogallala sandstone while the Arapahoe is usually on loess.

El Paso Series.---These soils have developed from loosely cemented sand derived from the Dawson arkose formation. The cementing material is thought to be largely feldspar kaolin. The soil occupies a variety of surface features ranging from gently undulating to strongly rolling, much of it occurs on low rounded divides between drainageways. All of the soil is well drained and in most places suffers rapid runoff for such a sandy soil, which probably accounts for the brownish color of its surface soil. Soils of similar texture developing in more nearly level situations usually have a dark grayish-brown surface soil. The native vegetation is mainly short grasses. The soil supports a very small proportion of tall grass species - yucca and cactus are common. Most of the soil remains in pasture, probably not over 10 percent is cultivated. Where cultivated, it seems a fairly good agricultural soil, but is subject to drifting. Corn and beans are main crop. Native grasses will support about 20 cattle per square mile for year round grazing.

A description of the loamy sand type follows:

Location - T. 13 S., R. 62 W., Section 5.

The profile here is about average for this soil as mapped in the Templeton Gap and Black Squirrel Creek projects (Soil Conservation Service projects). The topography at this point is favorable for the average soil development. It is on a long $5\frac{1}{2}$ percent slope.

- 0"-8" Grayish-brown loamy sand with no definite structure. This layer has barely sufficient fine material to give it moderate coherence.
- 8"-18" Brown light sandy clay loam. This is the heaviest layer of the profile. It is penetrated with considerable difficulty with digging tools, especially when dry, but a lump is crushed rather easily between finger and thumb. The cementing material is largely clay. The horizon is practically structureless but in places seems to have a weakly defined columnar breakage.
- 18"-30" Same as layer above except grayish-brown in color and considerably more friable, but still containing sufficient clay to make it firm in position.
- 30"-55" Light grayish-brown loamy sand containing a small amount of gravel ranging from about 1/8 inch to sand. This material contains some clay but not enough to give it notable coherence.

Below 55" the color and consistency remain about the same as layer above, but the gravel content increases considerably. The material is incoherent gravelly sand. The soil contains no lime at any depth. It was examined in a pit 4 feet deep below which it was observed in auger borings to 9 feet. This soil differs from Falcon in having a brown instead of dark brown topsoil and in having a more compact (in position) upper subsoil. This horizon is also finer than any in the Falcon loamy sand. It supports a much higher percentage of short grasses. It is closely associated in distribution with the Falcon loamy sand. The El Paso soils contain more clay or a clay that swells more on wetting than do the Otis soils. The Otis soils are developed on sands free of gravel while the El Paso soils are developed on arkose.

Otis Series.---These soils have developed from sand containing a moderate percentage of clay. They occupy nearly level to strongly rolling upland. The relief seems to be wind formed, but is not angular or choppy such as ordinarily occurs in areas of unstable sand deposits. In places the hillsides have been gullied locally by water erosion, indicating that the soil has sufficient body to prevent such rapid water absorption as occurs in typical dunesand.

Native vegetation is dominantly buffalo and grama grasses, long leafed reed grass, sage, yucca, needle grass, and big and little bluestem.

The profile is characterized by three fairly well defined layers. The surface layer averages about 8 inches thick, but ranges from 6 to 20 inches. It is brown to light brown sand to loamy sand with sufficient clay to give it considerable body. Below the surface layer, the material becomes gradually lighter in color, grading into light yellowish-brown within the 3 foot depth.

The greatest clay concentration is ordinarily between the depths of 12 to 24 inches. However, in places the clay is uniformly abundant to about 24 inches. The lower subsoil and substratum, although less well supplied with clay than the overlying layers, contains enough to make the sand rather firm when dry and slightly sticky when wet.

The entire profile and the parent material are non-calcareous to considerable depths. The more nearly level to gently undulating areas of the Otis soils have been mapped in Washington County as a "smooth phase" of the series.

The Otis sand differs from Dunesand, and the "smooth phase" differs from the Valentine soils as follows: Otis soils (1) have more stabilized surface, (2) higher clay content, (3) a more consistent growth of hardland grasses, (4) a more coherent profile, which enables it to stand vertical in excavations or cuts, a characteristic not inherent in dunesand and seldom inherent in the Valentine soils. The grass cover is better and range carrying capacity higher on the Otis soils.

The Otis soils have slightly darker colored surface soils and lime is leached to lower depths than in the Koen soils.

Valentine Series.---The Valentine soils have developed under a rather sparse grassy vegetation, from windblown materials composed largely

or entirely of sand. These materials, although subjected to some wind erosion since deposition, occupy lower and more protected situations and support a slightly heavier grass cover than typical dunesand. In most virgin areas they have accumulated enough organic and fine mineral material to darken slightly and to stabilize their surface layers. The Valentine soils, however, rapidly lose their organic matter and stability when the protective grass cover is destroyed.

These soils are chiefly in dry valleys, flats, and on rolling to hummocky land within and around sandhills. They are locally developed on stream terraces and flood plains wherever sandy materials of scant organic content have been piled by the wind into low hummocks and ridges. There is practically no surface drainage as the precipitation readily enters the porous soils.

The topography, although quite variable, does not attain the hilly and dune-like aspect so characteristic of sandhill land.

After Hayes:

The soil profile is immaturely developed. The topsoils, which are ordinarily less than five inches thick, are rather light colored, ranging from grayish-brown to dark grayish-brown, the shade depending upon the amount of organic matter which they contain. Few of them have more than 1.5 per cent of this material. They vary considerably in texture, but all of them are markedly loose and sandy. The medium sand, fine sand, and loamy sand textures predominate.

The remainder of the soil section consists of incoherent grayish-brown or light grayish-brown, fine to medium sand which extends to depths exceeding 3 feet.

The Valentine soils are structureless, lime free, and contain little or no gravel. Their outstanding features are the light color, sandy, lime-free, and loose, incoherent nature of their profiles.

The sands from which these soils have developed came from different sources in different localities. In northwestern and southwestern Nebraska, southern South Dakota, and eastern Colorado, they were released mainly through the disintegration of Tertiary sandstones. East of about the one hundredth meridian in Nebraska, most of them probably came from coarse pre-Peorian, Pleistocene materials, largely of the Grand Island formation which accumulated west of the Kansan glacier. These soils, over considerable areas in the Dakotas, have formed from sands which were deposited as sediments in the basins of old glacial lakes and as debris on the uplands when the glaciers melted. Some areas of Valentine soils are developed on wind-whipped, sandy, stream sediments in valleys and on sands blown out of stream beds onto the adjoining uplands.

The soils of this series differ from dune sand, chiefly in having a more nearly level surface and greater stability. They are confined to areas in which the local relief does not exceed 15 feet and in which the sandy material is fairly stable, considering its loose incoherent

nature. These soils represent the first stages of soil development from wind-blown sand.

The Valentine and Thurman soils occupy well drained positions, are composed largely of sand and are lime-free. The Thurman have been less affected by wind than the Valentine and have much darker and thicker topsoils. In many places they contain glacial debris, including scattered boulders and small amounts of fine and coarse gravel, not found in the Valentine.

In a few areas, the Valentine and Sparta soils are identical in profile features, differing only in topography and the manner by which their parent materials were deposited. The Sparta, which are only on terraces, have developed from sandy stream deposits and have nearly level surfaces, while the Valentine have been formed on wind-blown sands and, where occurring on stream terraces, have a strongly undulating to hummocky surface. In most areas of Sparta soils, the profile shows stratification and contains more or less gravel.

The Valentine have less fine material and are less stable than the Anselmo soils which, although composed largely of sand, are in transition areas, usually broad, high-lying valleys, between sandy and "hard" lands. The latter soils have accumulated considerable silt together with small amounts of clay and for depths of 2 or 3 feet have more coherence than the Valentine.

Differences in the drainage conditions, topsoil color, and lime content serve to distinguish the Valentine and Gannett soils, both of which are composed mainly of sand. The Gannett are in poorly drained valleys and pockets of sandy areas where vegetal growth and decay are rapid. They are much more calcareous, and have thicker and darker topsoils than the Valentine. In addition, their subsoils are more stained and splotted with very light grayish-brown and rusty-brown colorations than those of the Valentine soils.

The Valentine surface soils are less stable, have less clay in the profile and less short grasses than the Otis soils.

The Channing soils have somewhat lighter colored surface layers than the Valentine series, and also have lime in the subsoils.

Dunesand.---After Hayes:

Dune sand consists of incoherent fine to medium sand which has been whipped into strong relief by the wind. Dune hills and ridges, most of which rise 15 or more feet above intervening valleys, pockets and swales, are a characteristic feature of the landscape. Few of the depressions have surface drainage outlets, but the loose, porous sands absorb water rapidly and there are no surface accumulations.

This material is not a soil. The greater part of it now supports a sufficiently dense growth of tall grasses to prevent excessive wind erosion. Locally the decayed grass remains have slightly darkened the surface layer to a depth of one or two inches, but dune sand is uniform

in texture and consistency and in most places shows little or no color change from the surface downward. It is light grayish-brown in the northern and central prairie states but becomes slightly tinged with red in its more southern distribution.

In localities where the vegetative cover is destroyed, the incoherent sand is subject to almost continual shifting by the wind. Its high porosity has permitted thorough leaching of the lime to depths exceeding six or seven feet. It contains little material coarser or finer than medium and fine sand, respectively.

The greater part of the sand was released through the disintegration of Tertiary sandstones, although some of it undoubtedly came from water and ice deposits of later ages. The finer constituents of the source materials have long since been removed by the wind.

The outstanding features of dune sand are its light color, sandy, lime-free and incoherent nature, and the strongly rolling to hilly character of areas where it occurs. It is practically identical with Valentine sand from which it is distinguished chiefly on the basis of topography. Valentine sand is confined to areas in which few of the wind-formed knobs, hummocks, or ridges exceed fifteen feet in height, while dune sand has a more pronounced relief. The other Valentine types have slightly darker surface layers than dune sand in addition to their smoother topography.

Dune sand differs from Enterprise sand, dune phase, of Oklahoma and Texas, only in having a lighter, less brownish or pale-reddish color than the dune phase of the Enterprise.

Channing sand, dune phase, of the Arkansas Valley region differs from Dunesand only in the calcareous nature of sands below 2 to 4 feet. Dunesand has no lime in the upper 5 to 7 feet.

Otis sand often has a topography similar to Dunesand but its surface soils are more stable, due to a higher clay content.

Bridgeport Series.--After Hayes:

The soils of this series are immature, friable, and limy, with rather light to only moderately dark surface layers, and profiles of uniform texture. They are developing from recent alluvial and colluvial material, at or near the base of smooth slopes and on gently sloping terraces in western Nebraska and adjacent parts of South Dakota, Wyoming, Colorado, and Kansas.

There is sufficient gradient to prevent surface water accumulations, and the soils have good underdrainage. They are subject to only normal erosion.

The topsoils, which are grayish-brown or locally dark grayish-brown, are not generally more than 10 inches thick and may be much thinner. They range in texture from silt loam to loamy fine sand. None of them is heavy. Some contain scattered gravel, although this material is not usually abundant enough to alter the texture.

The remainder of the section is slightly lighter in color than the topsoil, but there is no appreciable texture change to depths below 3 feet. The profiles have columnar form, except in the more sandy types, which are rather incoherent. They are structureless and have not developed definite zones or layers of true soil character. The soil material is limy to or nearly to the surface of the ground.

The principal features of these soils are their rather light colored topsoils, the uniform texture profile, and the loose, limy, and immature nature of the soil section. The finer textured Bridgeport types are identical in profile features with the Mitchell soils which are developing on colluvial material washed from areas of Brule clay in western Nebraska and eastern Colorado. Some of the sandy types resemble the more calcareous soils of the Anselmo series. The Anselmo occupy higher lying (upland) positions and have, as a rule, better developed texture and consistency horizons than the Bridgeport.

The Bridgeport are limy, while the Valentine soils are lime-free. They have more uniform texture profiles than the Cheyenne and Tripp soils, both of which are on stream terraces. Furthermore, they are not as gravelly as the Cheyenne nor as maturely developed as the Tripp.

These soils occupy lower positions, have lighter colored topsoils and are less mature than the Rosebud and Keith soils, from which most of their parent material was derived. They are better drained than the Laurel soils of the bottomlands, and their subsoils are not stained and splotched rusty-brown, as are those of the Laurel.

The Bridgeport and Judson soils occupy similar physiographic positions, and their parent materials have accumulated in much the same manner. These soils have equally uniform texture profiles. The Judson, however, are developing in more easterly regions. They are dark and lime-free to depths exceeding 3 feet.

The Apishipa and Bridgeport soils are quite similar in all respects except surface soil color. The Apishipa is gray or light grayish brown from the surface downward, whereas the Bridgeport soils have grayish-brown or darker surface layers.

Cherry Series.—The Cherry soils occupy a few rather small areas on slopes of 6 percent or more in the vicinity of the Black Forest. These soils are intrazonal because their slope allows surface soils to be removed by erosion, before they can reach equilibrium with the local climate.

The following descriptions of the very fine sandy loam type is similar to the soil throughout its observed development.

- | | |
|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0"-3½" | Grayish brown single grain very fine sandy loam. |
| 3½"-6" | Grayish brown cloddy fine sandy clay loam. This layer is about the same color as the topsoil and altho moderately compact in place, crushes easily. |
| 6"-23" | Brown with faint red tinge columnar with cloddy to nutlike structure clay loam. This is by far the heaviest layer of section, but is not dense owing to its form and structure. A lump of this material cannot be crushed between finger and thumb when dry. |

Below 23 inches the material differs little in consistency and structure from layer above but is slightly lighter in color. In this particular locality the parent material only slightly modified by weathering occurs at 3 ft. This is a heavy sandy gravelly clay of brown to rusty brown color. It is practically impossible to extend the section deeper with spade or auger. The profile as a whole is non-calcareous, but small lime spots and splotches occur locally, usually below a depth of about 2 feet. The lime is very irregular in its distribution in many localities thruout areas of this soil.

The structure aggregates, that is, the nutlike lumps in the extremely heavy B horizon have in places sleek surfaces produced by colloidal material washed down from above.

The Cherry soils differ from the Weld series in the steeper slopes it occupies and the different parent material. Weld is developed on loess, and Cherry as stated above. The Limon soils occur on areas more nearly level than those occupied by the Cherry series, and they also have heavier clay subsoils.

LIGHT BROWN ZONE.--- Intrazonal soils developed only in the area in eastern Colorado giving rise to gray semi-desert soils owe their immature development to the nature of the parent materials. They are sandy soils developed on calcareous soft sandstone modified or transported by wind action. The low precipitation has been insufficient to remove the lime below 2 or 3 feet even on the porous sands.

Channing Series.---These soils occupy the sandhill areas on the more nearly level to undulating or slightly hummocky areas.

There is apparently no difference in color from the surface downward in the soil profile, which is yellowish brown or very light grayish brown throughout. The material is incoherent fine to medium sand, limy below depths of 16 to 30 inches. The surface is fairly stable where the grass cover has not been destroyed by overgrazing.

The "dune phase" of Channing sand differs from the typical Channing sand only in the more strongly rolling and hilly character of areas it occupies. It also is spotted by occasional blowouts or areas that are shifting so frequently that vegetation is not established.

The Channing series differs from the Valentine soils only in the usually lighter colored surface soils and limy subsoils of the Channing group.

Dune phase of Channing sand differs from Dunesand only in the occurrence of lime in the subsoil of the former.

Koen Series.---The Koen soils occupy sandhill, upland and terrace positions. They consist of medium to fine sand with enough clay to make them stand in vertical cuts. They are probably developed in both the "brown" and "light brown" zones, but have been observed only in the latter.

There is little or no difference in color from the surface down, and usually little difference in texture although the sand below 30 inches

often seems less coherent than that above. Below 12 to 24 inches the sand is quite calcareous.

Topography of the Koen soils varies from nearly level or slightly hummocky to regular high rounded sandhill relief. The soils on less abrupt slopes may be designated a "smooth phase."

The Koen series contain lime in the subsoils and the Otis series does not. Otherwise the two series do not differ. The Koen soils often have lighter colored surface layers, however.

The Channing soils are less coherent than the Koen series. Otherwise, these 2 series are quite similar.

Non-Zonal

In eastern Colorado there are several soil series and types of exposed parent materials which may occur in any part of the region. They are intrazonal because they lack normal development or have passed the stage of normal development, and may be considered "post mature." The latter is represented by one soil series.

Butler Series.—The Butler soils in eastern Colorado occupy shallow depressions or intermittent lake beds throughout the finer textured uplands. In the zone giving rise to "dark brown" soils the depressions usually occur on the more nearly level portions of the uplands, while in the zone giving rise to "brown soils" the intermittent lake beds are within gently rolling upland areas. In the "light brown" zone no depressions have been observed. Underdrainage from the depressions is very slow and surface drainage is absent. A large part of the water that collects in these areas evaporates.

After Hayes:

The topsoils, which range in thickness from about 12 to 18 inches, are very dark grayish-brown to almost black. They consist mainly of silt loam, are quite friable, and usually have 3 well defined structural layers. The upper one is single grained and is mulch- or dust-like when dry. It does not exceed 2 inches in thickness. The second is 2 to 4 inches thick and has a laminated or platy structure. The lower is finely granular, usually throughout, but in some places the material near its base has been considerably lightened in color by leaching and has developed an ill-defined laminated structure.

The subsoil includes 2 horizons. The upper is a true claypan. It begins abruptly beneath the topsoil, is 8 to 20 inches thick, and consists of very dark grayish-brown, dense clay which is almost impervious to water. The clay is structureless and upon drying breaks into lumps having numerous sleek surfaces and irregular shapes and sizes.

The lower subsoil layer, which is separated from the claypan by a transition layer of dark grayish-brown, moderately compact silty clay loam, 6 to 12 inches thick, is the horizon of maximum carbonate accumulation. It is friable, light grayish-brown silt with scattering rusty-brown stains and an abundance of lime. The carbonates are most concentrated in the upper foot of the horizon, where much of the lime is in

small, hard, and soft concretions. They decrease downward and may disappear at or near the 7-foot depth, which is about the base of the subsoil.

Beneath the subsoil is Peorian loess, a grayish-yellow floury silt with scattered rusty-brown stains and spots. The loess may be calcareous but if so, its lime is in disseminated form and rather low in amount. All of the material beneath the claypan has columnar form but is otherwise structureless.

The principal features of these soils are deep, dark and friable surface layers, underlain by a dark claypan; friable and light colored lower subsoils with a zone of carbonate accumulation, and a substratum of Peorian loess.

Arena Series.--The Arena soils are developed on clay shale parent materials which are usually quite high in salt content. They occupy swales, depressions or valleys along streams where drainage is poor.

The surface 3 to 6 inches of these soils are dark brown to light brown in color and are usually very high in salts. The underlying material is mottled rusty-brown, bluish-gray and light brown. The subsoils and often the surface soils are heavy clays. The color of the soil is dominated by the color of the parent materials so is quite variable.

The Arena series have subsoils higher in clay and generally darker surface soils than are usually found in the Laurel soils. The Orman soils are better drained than are the Arena soils.

Goshen Series.--The soils of the Goshen series have been mapped, as yet, only in small and widely scattered areas in Scotts Bluff County, Nebraska and Goshen County, Wyoming, where they occupy less than 9000 acres. The first areas--mapped in a rather general survey in 1913--were later found to include soils having a wider variety of characteristics, both internal and external, than should be permitted in a single soil series. The territory occupied by these areas was included in a more detailed survey in 1917, when the Goshen series was redefined.

This series, as now recognized, includes moderately heavy and dark soils of shallow basins and swales around or near the heads of drainage ways in the Dark Brown and Brown soil provinces. These soils have developed from rather fine textured materials, a part of which weathered in situ from underlying Tertiary sandstones and clays but most of which came from adjacent higher land through colluvial action. Both surface- and under-drainage are slow but water seldom stands on the land long enough to injure plants or prevent farming operations.

The upper part of the soil section consists largely of dark colluvial material. The topsoils, which are quite uniformly dark grayish-brown, average deeper than those of most other soils in this region, ranging mainly between 10 and 15 inches in thickness. They have a fine-crumb structure with a thin surface mulch and are friable throughout. The silt loam, loam, and very fine sandy loam textures predominate.

Beneath the topsoil is a moderately heavy but not compact layer of silt loam or silty clay loam containing a small amount of sand. This layer, which is fairly friable and from 10 to 15 inches thick, is almost as dark, especially in the upper part, as the topsoil but gradually becomes more grayish

and looser downward. It has a fairly well developed prismatic structure.

The lower part of the subsoil consists of light gray friable silt loam or very fine sandy loam having about the same consistence as the topsoil. It has no definite structure. A pronounced zone of lime accumulation occupies the basal part of this layer and rests on the parent material at about a 4-foot depth.

The Goshen soils do not differ greatly in profile features from some of the other soils on the uplands in this region. Were it not for their depressed positions, and consequently more favorable moisture supply, a part of them could be included with the Rosebud soils. They have, however, somewhat thicker topsoils, a little heavier upper subsoils and slightly deeper lying zones of carbonate accumulation than occur in most soils of the Rosebud series. Moreover, they have developed partly from colluvial deposits, whereas, the Rosebud are entirely on weathered material lying in situ on the underlying sandstones.

The Goshen and Dunlap soils are somewhat similar but the former are in depressed areas and have darker upper subsoil horizons than the latter. None of the Dunlap soils are developing on colluvial deposits.

The Goshen and Dawes soils occupy similar topographic positions but the Dawes have thinner topsoils, as a rule, and heavier and more definitely prismatic upper subsoil horizons.

The Scott soils differ from the Goshen in having thinner topsoils, much heavier and more massive subsoils, poorer drainage, and no lime.

The greater part of the Goshen soils are well suited for dry farming. All of them receive considerable moisture through run-off from higher levels in addition to the precipitation, and crops are not injured as frequently by drought as on the higher land. These soils are used principally for growing wheat and oats both of which yield as high as any of the associated soils of the uplands, or a little higher.

Although the Goshen soils are treeless, it seems likely that shelterbelts of drought resistant tree species could be established providing the run-off from more elevated areas is judiciously used. These soils have rather slow infiltration capacities and any surplus surface water must be held on the land much longer than it would naturally remain, if it is to penetrate through the heavy upper subsoil layer and be of much benefit to tree roots.

Apishipa Series.--On gently sloping lower terraces (or high bottoms) in the Arkansas Valley and on some colluvial slopes throughout eastern Colorado are deposits of very light grayish-brown fine sands to clay loams. The deposits are uniform in texture to depths of 3 feet or more and are so recent in deposition that they are uniformly light colored and highly calcareous from the surface downward. These deposits have been designated as the Apishipa soil series.

The Apishipa soils have little structure. The finer textured members are somewhat columnar in cuts but in general they are structureless throughout.

The Rocky Ford series has a slightly brown stained 3 to 5 inch surface layer and a very light colored raw appearing subsoil, while the Apishipa is uniform in color from the surface down. These 2 soil series are quite similar in all other respects.

The Bridgeport and Apishipa soils occupy similar topographic positions and originate from similar parent materials, but the surface soils of the Bridgeport are generally darker colored and lower in lime content than the Apishipa upper layers.

The Manvel soil series as mapped in the Arkansas Valley but not separately described here apparently differs from the Apishipa only in the rather regular occurrence of gravel and coarse sand below 3 to 5 feet, and the irregular "spotted" occurrence of a darker colored surface layer of 6 to 14 inches.

Orella Series.--- In some of the earlier soil surveys, a group of rather inextensive, mostly shallow, light colored, and immature soils, developing in situ on the Chadron formation of early Tertiary age, or on material resembling this formation in general character, were classed as Orella soils. All of these soils, as yet mapped, are in the Dark Brown soil region --- Dawes, Sheridan and Scotts Bluff counties, Nebraska and Goshen County, Wyoming --- where they are developing under a rather low precipitation, a dominantly short grass cover, and slow vegetal decay. They are not highly productive even where irrigated.

Although most of the Orella soils, that have been mapped, are on one or another of the beds belonging to the Chadron formation, this formation is extremely variable. It is nearly everywhere calcareous and consists mainly of variegated gray, green, and red, rather firmly cemented sandy clay but includes beds of light gray, almost pure clay or silty clay, and of greenish-gray, arkosic sandstone. Near its base are coarser beds, including deposits of gravel. In addition to its lithologic variations, the areas in which this formation is furnishing parent material for soils vary in their surface features, drainage conditions and physiographic position.

Differences in the character of the Chadron materials and in the general environment under which the soils on these materials are developing have resulted in wider soil differences, both internal and external, than should be permitted in a soil series. For this reason it seems necessary to redefine the Orella series so that it may include soils which are more nearly uniform in characteristics, type of parent material, and environment, than those formerly classed in the series.

In the light of recent observations by the writer, both in the areas already mapped as Orella soils and in localities outside these areas, he feels that the Orella series should not be permitted to include any soils which are naturally poorly drained, which contain sufficient gravel to notably increase their infiltration capacities, or which occupy stream bottoms or terraces, even though they may be developing on material of strictly Chadron origin. If these exceptions are recognized the soils now mapped under the name Orella are sufficiently uniform in their internal and external properties to belong in the same series.

On the basis of present information, it seems advisable to include in the Orella series all soils developing in situ from variegated gray, green, and red clays and heavy sandy clays of late Cretaceous or early Tertiary age, on well to excessively drained uplands in the northern Dark Brown and Brown soil provinces. These soils are developing under a low precipitation, short grasses, and slow vegetal decay, and have accumulated only a little organic matter. Their topsoils are grayish-brown or locally dark grayish-brown, are rather heavy and intractible with no well defined structure, and do not ordinarily exceed 7 inches in thickness. The clay, clay loam, and sandy clay loam

textures predominate, although coarser textures are common. The topsoils rest on light gray heavy massive clay, silty clay or sandy clay, which in most places is at least faintly splotched or streaked with greenish or roddish colors. This, the partially weathered but otherwise little modified parent material, ranges in thickness from a few inches to about 2 feet. It overlies rather firmly cemented gray clay or sandy clay of the unweathered formation in which either green, red, or both colors, are conspicuous.

The Orella soils are highly calcareous from at or near the surface downward. In most areas of these soils the Chadron formation is exposed at places. This formation erodes easily and in some areas has been carved into extremely rough and broken relief. It is associated with the overlying Brule formation in the badland areas of South Dakota there it is responsible for much of the color variation in the bluffs, knobs, and other rough forms of these areas.

The soils of this series are closely associated with the Epping soils in certain localities but are on heavy and markedly variegated clays and sandy clays, whereas, the Epping are on rather uniformly gray to pale pink relatively silty beds. Both soils are developing in situ on either the Chadron or the Brule formation, but the Orella soils are principally on the former and the Epping on the latter.

The Orella soils are too heavy to absorb much of the rather low precipitation in the region of their occurrence. They are not well suited for the production of cultivated crops under dry farming methods, chiefly on account of their low infiltration capacities and high wilting coefficients. Wheat, rye, and barley, receiving no moisture except that supplied by precipitation, are grown on a few fallowed fields of these soils but the yields are low except in unusually wet seasons. Some of the Orella soils in the valley of North Platte River are irrigated and used mainly for growing sugar beets but most of them still remain with their native cover of grasses and are included in cattle ranches. The heavier textured types of this series support a rather sparse grass cover and do not have high value even for grazing purposes.

These soils are poorly suited for growing trees except under irrigation. What little moisture they are able to absorb from the rather low precipitation is held too high in the soil section to be of much benefit in tree roots.

Epping Series.--The Epping series includes shallow, immature, and rather light colored soils developing under good to excessive surface drainage on the more silty and less variegated beds of the Brule and Chadron formations. These soils are in the northern half of the Dark Brown and Brown soil provinces. The largest areas are in western Nebraska and adjacent parts of South Dakota, Wyoming and Colorado where the Brule or Chadron outcrop rather extensively in certain localities. These formations differ markedly in their faunal content and to a less pronounced degree in other properties. Both are of early Tertiary age but the Brule, which overlies the Chadron is, as a rule, the more silty and less variegated of the two. At most places it consists of rather uniformly light gray or pale pink, massive and limy silty clay. It is on this particular material of the Brule, and on like material of the Chadron beds, that the Epping soils are developing. The silty clay has a moderately firm consistence, low infiltration capacity, and erodes easily. Only a little of its weathered surface material remains in situ for soil development.

The relief in areas of these soils ranges from gently to steeply sloping and, owing to slow water absorption by the underlying silty clay, most of the precipitation runs off the land. The supply of soil moisture, although low, has been sufficient to support a short grass cover, except where erosion

has been unusually severe, but vegetal decay is slow and much of the organic matter is removed through run-off almost as fast as formed.

The surface layers of these soils do not exceed 7 inches in thickness, except locally. They are silty and friable but have accumulated only a little decayed vegetation and ordinarily are lighter than dark grayish-brown. They overlie a uniformly limy layer of almost white silty clay which has been largely reduced to a floury consistence, but which still contains partially disintegrated and moderately hard lumps of the underlying formation. The entire solum is less than 2 feet thick, at most places.

Nearly all areas of Epping soils include light colored patches in which the Brule or Chadron formation is exposed. Where severely eroded these formations give rise to extremely rough and broken relief, as in the scenic badland areas of South Dakota and in small patches of incipient badlands near Chadron, Crawford, and Scottsbluff, Nebraska; northwest of Akron, Colorado; and elsewhere.

In a few places, close observation is required in order to distinguish the Epping from the Colby soils, especially in localities where the two are associated. The Epping soils, however, are developing in situ on the Brule and Chadron formations, partially weathered fragments of which occur in the lower part of the solum. The Colby soils may also be developing on Brule and Chadron material, but if so, this material has been transported to its present position by wind, contains no unweathered fragments, and is strictly loess-like in character.

The Epping and the Orella soils are somewhat similar in certain localities but the Epping are on the more silty and less variegated beds of the Brule and Chadron formations, whereas, the Orella soils are chiefly on the more variegated--gray, green, and red--sandy clay and clay beds of the Chadron formation.

None of the Epping soils is well suited for cultivated crops, even under dry farming methods, chiefly on account of the thin surface soil and slow filtration rate. Many tracts are too gullied for cultivation. Some of the smoother areas are used for growing wheat, barley, and rye but satisfactory yields are obtained only in years of high precipitation. The greater part of these soils remains with its native cover of buffalo and grama grasses and is included in pastures.

A few ash, elm, and hackberry trees are on the beds of drainage ways in some of the Epping soil areas but elsewhere these soils are treeless except for an occasional low and scrubby red cedar which probably grew from seed dropped by birds. Without supplemental water satisfactory tree shelterbelts cannot be established on any of the soils belonging to this series.

Pierre Series.--After Hayes:

The Pierre soils have moderately dark topsoils and dense, clayey or shaly subsoils. They have developed under a grassy vegetation from heavy shales and clays of the Pierre formation.

These soils cover large and small areas in the short-grass region of the north-central prairie states wherever the Pierre beds are near the surface. They are extensive in the Dakotas, Wyoming, Colorado, and northwestern Nebraska.

The relief ranges from nearly level and gently rolling over large tabular areas to extremely rough and broken in some of the more deeply entrenched valleys. Surface drainage is nearly everywhere adequate. On the steeper slopes rapid runoff causes severe erosion. The dense clays and shales practically prevent underdrainage.

The topsoils are grayish-brown to dark grayish-brown and are not more than 10 inches thick. The clay, silty clay loam, and clay loam types predominate. The material shows no structural development and is friable only under a narrow range of moisture conditions. It becomes extremely sticky and plastic when wet and hard and tough when dry. In the latter condition, it is subject to excessive shrinking and cracking.

The remainder of the soil section, which merges with the topsoil through a thin transition zone, consisting of slate colored to grayish-brown dense clay, is composed of a grayish-blue to dark grayish-blue mixture of clay and shale. The shale is in various stages of decomposition but becomes less weathered and firmer downward. The unaltered, or only slightly modified Pierre formation, is generally within a depth of 3 feet.

In the rougher localities the topsoil and transition zone have been removed by erosion.

The Pierre soils are ordinarily calcareous at and below a 10-inch depth, and in numerous places they are limy on the surface. A zone of carbonate accumulation may begin at any depth between 10 and 20 inches but is not usually pronounced. This zone and the underlying shale contain considerably gypsum in many localities.

The principal features of these soils are their moderately dark surface horizons, the heavy, clayey, and shallow nature of the soil section, and the substratum of Pierre shales and clays.

The soils of the Pierre series rest on the same geologic formation as that underlying the Boyd soils farther east and are similar to those soils in many respects. They have developed in a region of lower precipitation, sparser grass cover, and less rapid vegetal decay than the Boyd soils and have lighter colored topsoils. They are the northern Dark Brown while the Boyd are the northern Chernosem representatives of the Pierre shale-derived soils.

The Pierre and Orman soils are almost identical in profile features. The Pierre are in the uplands where they have formed from the Pierre formation in situ, while the Orman have developed on stream terraces from water-reworked shales and clays of this formation.

The Pierre and the more westerly distributed Edgeley soils are somewhat similar, but the former have developed from the underlying shale and include no glacial material, while the latter have formed over ice-laid mixtures of shale, gravel, and sand and are coarser textured.

The Pierre are much denser than the Dawes soils, which, although fine textured, have developed from less compact, lighter colored, and younger formations.

The Pierre soils are shallower to shale than are the Boyero soils. Boyero soils are developed on reworked clay and wind modified materials and are usually 3 feet or more from the surface to clay shale.

In most places in Colorado the Pierre soils might as readily be classed with intrazonal as with zonal soils. They occur in all parts of the region and owe their dark color to the color of the parent shale rather than to the accumulation of organic matter.

BROWN SOILS.—The brown soils in Colorado develop under a mean annual precipitation of about $13\frac{1}{2}$ to 17 inches and a mean annual temperature of about 45° to 55° F.

These soils have friable surface and subsoils, and differ from the dark brown soils only in color of surface soil and depth of profile. Their lighter color is due to less grass growth and decay, hence, a lower percentage of organic matter in the surface soil. Lime zones occur at somewhat shallower depths in the brown than in the dark brown soils.

The brown soils occupy extensive areas throughout most of eastern Colorado, and represent areas wherein a very careful system of farming is necessary to produce field crops at a profit.

Larimer Series.—The Larimer soils have developed on tertiary deposits of gravel, fine sands and clay with a moderate to very high lime content. They generally occupy nearly level to gently rolling areas throughout eastern Colorado, north of the Arkansas River.

Near the mountains there is considerable variation in the mean annual temperature and precipitation within short distances, and in this vicinity small areas of the soils have been mapped that have dark enough surface soils to be included in the dark brown soil group. In general, however, these soils have brown or grayish-brown surface soils and definitely belong in the brown soil group.

The surface soils are chiefly loam, very fine sandy loam or fine sandy loam, grayish-brown or somewhat reddish-brown in color, coarsely cloddy, or structureless, and 6 to 15 inches thick. They are non-calcareous and usually contain a rather high percentage of small granitic gravel which is usually angular.

Canyon Series.--After Hayes:

The Canyon soils are immature, shallow, and stony. They are developing in the drier parts of the Great Plains region from light colored, limy, and soft sandstone and "mortar bed" deposits of Tertiary age. Most of them are within or near areas of Rosebud, Akron or Larimer soils, where they occupy knobs, ridges, and slopes on which soil formation has been greatly curtailed by erosion.

Where best developed, these soils have light grayish-brown to dark grayish-brown, friable topsoils not usually exceeding 7 inches in thickness. Silty to only moderately sandy types predominate.

The subsoils, where present, are very thin and poorly developed. In most places the topsoils rest almost directly upon the weathered limy bedrock. Fragments of this material, together with water-worn granitic gravel and pebbles may occur on the surface of the ground and throughout the soil section. The unweathered or only slightly modified stone is generally within a depth of 2 feet. It outcrops at numerous places, giving the land a spotted dark and light appearance.

The distinguishing features of these soils are their immature and stony character and the shallow depth to the parent Tertiary sandstone.

The Canyon soils are less mature than any other soils developing on similar parent material in the northern Great Plains. They somewhat resemble the shallow and immature Potter soils of the more southern latitudes. The Canyon and Potter have developed under similar topographic and drainage conditions and from material of the same general color and age. The substrata of the Canyon consist of sandstone while those of the Potter are composed of limy silts and clays.

The Canyon are developing on younger and more sandy formations than the Sogn soils.

Owing to their shallow and stony nature, practically all areas of these soils are used for grazing purposes.

Sogn Series.--After Hayes:

The Sogn series includes immature, shallow, and stony soils that are developing from Permo-Pennsylvanian limestone and Cretaceous chalk rock in the Pedocal-soil region of the central prairie states. They are chiefly in Nebraska, Kansas, and southern South Dakota, but also are developed in parts of eastern Colorado.

The relief is steeply sloping to hilly, and run-off is everywhere rapid. All of these soils are subject to severe water erosion.

Where best developed, the Sogn soils have very light grayish-brown to almost black, silty topsoils, which do not usually exceed 7 inches in thickness. The subsoils, where present, are very thin and poorly developed. In most places the topsoils rest almost directly on the weathered bedrock, fragments of which are on the surface of the ground

and throughout the soil section. The unweathered, or only slightly modified stone is generally within a depth of 2 feet. It outcrops at numerous places, giving the land a spotted light and dark appearance.

The principal features of these soils are their immature and stony character and the shallow depth to the parent soil material.

Throughout the region of their distribution, the Sogn soils are shallower and less mature than any other soil that has developed from limestone or chalk rock.

Although the Sogn soils originated in regions of more precipitation than falls in eastern Colorado, the immature LaPorte soils of the "brown" soil region and "shallow phases" of Penrose soils in the "gray semi-desert" region can well be included in this soil series. They are all very shallow soils on limestone or chalkrock.

Rough Broken Land.--Throughout eastern Colorado are steep to rough and broken areas, some of considerable extent. Most of the areas are steep slopes and precipitous exposures with very little or no evidence of soil formation. Loess, Tertiary, Laramie, Foxhills, Pierre, Niobrara, Benton, and other geological deposits occupy areas designated as "rough broken land." Rough broken land does not occupy the high foothills and mountains nor is it usually as rocky as "rough mountain land."

Rough Mountain Land.--The foothills and slopes to higher mountains along the range front in eastern Colorado are classed as rough mountain land. In such areas slopes are steep to precipitous and rocky. A great variety of geologic formations are represented in the materials on these slopes. There is little sign of soil formation on rough mountain areas, but they might be subdivided on the basis of the type of parent materials they represent.

Cass Series.--After Hayes:

The soils of the Cass series are dark, immature soils which are developing from coarse textured sediments, chiefly sands and gravels along drainageways in the central and northern prairie states.

These soils lie only a few feet above the normal level of the streams and are subject to overflow during periods of high water. When the streams subside, the surplus moisture soon drains off the land or percolates downward through the porous sands. The soils do not usually remain water-logged more than a few hours except in scattered pockets and swales. The water table is nearly everywhere within a depth of 10 feet and during wet seasons rises sufficiently to produce temporary marshes in some of the lower situations.

The topsoils are very dark grayish-brown and about 8 to 12 inches thick. They range widely in texture but in most places are composed largely of fine or very fine sand together with sufficient organic matter to give them a dark color and loamy texture.

The remainder of the soil section, which is normally grayish-brown or light grayish-brown, consists of incoherent sand or a mixture of loose sand and gravel that has been little altered since deposition. Rusty-brown stains, streaks, and splotches are common in the lower part of the section.

The Cass soils may contain lime but where they do, the carbonates are in finely-divided form and are evenly distributed throughout the profile.

The principal features of these soils are the very dark color of their topsoils, the light colored, sandy, and incoherent nature of their subsoils, and the shallow depth to the water table.

The Cass soils differ from those of the Lamoure series in having coarser textured, less coherent and less limy profiles. They resemble the Sarpy soils in all features except topsoil color. The Sarpy topsoils are low in organic matter and light in color. The Cass are much more sandy and incoherent than the Wabash soils.

The Sioux and O'Neill soils of the sandy or gravelly terraces are somewhat similar to the Cass in general appearance but are better drained, have better developed profiles, and occupy higher positions.

Sarpy Series.---After Hayes:

The Sarpy series includes light colored, immature soils that are developing on flood-plains along drainageways from recently deposited coarse textured sediments, mainly sands and gravels.

These soils are chiefly in the northern and central prairie states but occur locally in eastern Colorado. They lie only a few feet above the normal level of streams and are subject to overflow during periods of high water. When the streams subside, the surplus moisture soon drains off the land or percolates downward through the porous sands. The water table is nearly everywhere within a depth of 10 feet and during wet seasons rises sufficiently to produce temporary marshes in some of the lower situations.

The topsoils, which are about 4 to 6 inches thick, contain barely enough organic matter to give them a grayish-brown or locally dark grayish-brown color. They range widely in texture but ordinarily consist of fine or very fine sand. When cultivated they are subject to considerable drifting during prolonged dry windy periods.

The remainder of the soil section is normally light grayish-brown. It consists of incoherent sand or a mixture of loose sand and gravel that has been altered only slightly since deposition. Rusty-brown stains, streaks, and splotches are common in the lower part of the profile.

The Sarpy soils may contain lime, but where they do, the carbonates are in finely divided form and are evenly distributed throughout the soil section.

These soils represent a very early stage of soil development from sandy alluvium. With the incorporation of sufficient organic matter to make their topsoils dark, they will change to Cass soils. The latter, after deeper stream entrenchment, thereby preventing overflow and facilitating better underdrainage and aeration, will ultimately become Sioux soils if they remain calcareous, or O'Neill soils if leached of their lime.

The outstanding features of the Sarpy soils are the light color of their topsoils, the incoherent sandy or gravelly nature of their subsoils, and the shallow depth to the water table. These soils differ from those of the Cass series only in having thinner and lighter colored topsoils. They are similar in many respects to the Sparta soils, which, although light colored and composed largely of incoherent sand or gravel are on terraces and have better drained and less stained and spotted subsoils than the Sarpy.

The Sarpy soils are often as light in color as the Laurel soils but usually do not contain as high percentage of soluble salts, and are developed from coarser textured alluvium.

Lincoln Series.--After Hayes:

The Lincoln soils are brownish, immature, and calcareous soils which are developing on sandy sediments of similar or slightly lighter color in the bottom lands along drainage ways. They lie only a few feet above the normal level of the streams and are usually rather poorly drained, especially in the lower part of the soil section. All of them are subject to overflow during high stages of the streams. The native vegetation formerly included mixed growths of grasses, forest, and shrubs, but most of the higher lying and better drained areas have been cleared for cultivation.

The topsoils are brown, dark brown, or grayish-brown, the color varying with the organic content. The remainder of the soil section becomes increasingly lighter with depth, usually being light grayish-brown in the lower part. It consists mainly of sand and may range in texture from incoherent, almost pure sand, to loosely coherent very fine sandy loam. The soils are too young to have developed a carbonate zone and textural horizons of true soil character. They are limy downward from at or near the surface and may contain thin depositional strata of coarser and finer sediments in any part of the section.

The principal features of these soils are their brown to grayish-brown profiles, the loosely coherent to incoherent nature of the material beneath and frequently including the topsoils, and the high-lying lime supply.

The Lincoln soils have little or no red in their profiles which distinguishes them from the Yahola soils. They may be regarded as the bottom-land equivalents of the more sandy types of Canadian soils but are not so well developed or as deeply leached of their carbonates as the Canadian.

These soils are chiefly in Kansas and Oklahoma where they have about the same textural range as the Cass and Sarpy soils of Nebraska, Iowa, and the Dakotas. Their topsoils are not generally so intensely dark as those of the Cass, and in most places, are a trifle darker than those of the Sarpy soils. They have, however, a color range which would include both the Cass and Sarpy of more northern states.

Minatare series.--The Minatare series includes poorly drained, rather light colored, calcareous soils developing from clay, silty clay and heavy sandy clay sediments on nearly flat bottomlands. These soils have been mapped, as yet, only in the Dark Brown soil province, chiefly in western Nebraska and eastern Wyoming, but probably are azonal as they owe their features more to their immaturity, the drainage conditions, and the character of the parent sediments than to the regional environment. They lie only a few feet above the normal level of the streams and are inundated during flood stages. The water table is within a depth of 8 feet, at most places, and in wet seasons rises enough to water-log the entire soil section, except where the land is artificially drained.

The topsoils are from 7 to 14 inches thick, are rather low in organic matter, and have no well defined structure. They range from dark grayish-brown to grayish-brown, the former color predominating. The material composing them is most commonly a loam, silt loam, or very fine sandy loam of friable consistence but locally consists mainly of clay.

The remainder of the soil section is quite variable but everywhere contains a heavy layer of clay, silty clay or sandy clay. This layer is mottled gray, white, and rusty-brown and ranges from about 15 inches to more than 3 feet in thickness. It is sticky and plastic when wet and hard when dry. The layer may begin immediately beneath the topsoil or may be separated from it by a few inches of light gray friable silt loam to fine sandy loam. It generally is underlain by a loose sand or sand-gravel mixture within a depth of 4 feet.

The soils are calcareous, downward, from at or near the surface but include no zone in which the carbonates have accumulated through soil forming processes. In places, salts consisting principally of sodium carbonate, sulphate and chloride and calcium sulphate and chloride, are present in sufficient quantities to injure the vegetation.

The sediments on which these soils are developing came largely from the Brule and Chadron formations. Greenish splotches so characteristic in some of the Chadron beds occur at places in the subsoils.

The soils of the Minatare series differ from Laurel soils mainly in having a heavy layer in their subsoils. They have much lighter colored surface layers than occur in the soils of the Lamoure series, but the topsoils are darker than those of the Billings soils which are almost white from the surface downward.

Prior to the development of irrigation in western Nebraska and eastern Wyoming, these soils supported dense stands of mixed salt, grama, western wheat, and other alkali resistant grasses. A large part of the soils are now within irrigation districts, where they occupy the lowest levels and receive much of the rather alkaline seepage water from higher irrigated lands. In some areas they have become so poorly drained and saline that only a rather sparse growth of salt grass remains. Where ditched or tilled, the soils are well suited for the production of native hay, and give fair yields of sugar beets. Phosphate fertilizer increases the beet yields on most of the soils and on some is necessary before beets can be grown profitably.

Only a few trees, chiefly willows and cottonwoods, are growing on Minatare soil, probably because of the high salt content. Where these soils are artificially drained nearly all trees suited to the thermal conditions should do well, especially after the roots are below the zone of maximum salt concentration, which usually is within the upper 12- or 14-inch layer of the profile.

Laurel Series.--After Hayes:

The Laurel are immature, limy, and rather light-colored soils which are developing on fine-textured or only slightly sandy bottom land sediments. They are in the drier regions of the central and northern prairie states.

These soils lie only a few feet above stream beds and are inundated during flood stages. There is usually sufficient slope, however, to prevent prolonged accumulations of surface water. Except in scattered pockets and swales, the soils remain water-logged only for short periods. The water table is nearly everywhere within a depth of 15 feet, and during prolonged wet seasons may rise sufficiently to produce temporary marshes in some of the lower situations.

The topsoils, which are grayish-brown to dark grayish-brown, are usually less than 10 inches thick. They include a variety of textures but in most places consist of silt loam, very fine sandy loam or fine sandy loam.

The remainder of the section is friable, grayish-brown to light grayish-brown silt to fine sandy loam, with numerous rusty-brown stains, streaks, and splotches. It merges with the parent sediments, usually within a 2-foot depth.

The soils are highly calcareous below the upper 5- or 6-inch layer and may be limy at the surface. Locally they contain sufficient alkali to injure vegetation. They break columnar upon drying but have not developed structure, and aside from their slightly darkened topsoils, they show no zones of true soil character.

The principal features of these soils are the rather light color of their topsoils, the fine textured or only slightly sandy nature of their subsoils and the friable, limy, and immature character of the soil section.

The Laurel occupy lower and more poorly drained positions than the Tripp and Bridgeport soils and are not nearly so well developed as the former. They are finer textured and more limy than the Sarpy and Cass soils and have lighter colored topsoils than the Cass. The Laurel differ from the Lamoure soils of more eastern bottom lands chiefly in having lighter colored and thinner surface layers. They resemble the Genesee soils in most profile features but are limy, while the Genesee are lime-free.

Lamoure Series.--After Hayes:

The Lamoure series includes very dark, immature, and calcareous soils which are developing along drainage ways from fine-textured sediments, chiefly silts and clays in the northern prairie states.

Areas of these soils lie only a few feet above the normal level of the streams and are subject to overflow during periods of high water. Surface- and under-drainage are slow, but the soils as a whole are not poorly drained except in the lower-lying situations. The water table is

ordinarily within a depth of 6 to 8 feet and during wet seasons may rise sufficiently to produce temporary marshes in the more depressed localities.

The topsoils are very dark grayish-brown or almost black and about 10 to 14 inches thick. They range rather widely in texture, but loams, silt loams, and clay loams predominate.

The remainder of the soil section consists largely of silty and clayey sediments which have been little altered since their deposition. It is normally rather heavy, owing to a high clay content, but is friable in localities where it is composed largely of silt. At places, the Lamoure soils contain considerable sand but not enough to decrease their coherence greatly.

The color of the material beneath the topsoil depends upon the conditions of drainage and aeration. In the better drained localities, it may be almost black to depths exceeding 3 feet. In most places it becomes lighter downward and in poorly drained localities there are numerous rusty-brown and black spots, splotches and streaks in a light grayish-brown or yellowish-brown matrix.

Lime is normally present throughout the soil section and is abundant in the lower half but has not accumulated in a definite band or horizon. Locally the Lamoure soils contain sufficient alkali to injure vegetation.

The principal features of these soils are their very dark topsoils and the immature, limy, and fine-textured but not dense character of their profiles.

The Lamoure differ from the Cass soils, with which they may be associated, in having finer-textured, more coherent, and more limy profiles. They are much more calcareous than the Wabash soils and have darker surface layers than the Laurel soils.

Riverwash.---After Hayes:

Riverwash includes a wide variety of more or less stratified sediments that have been recently deposited by streams. It is principally in narrow, usually broken strips, on flats, bars, and low levees near the stream banks, but also occurs on most of the islands and is on the beds of many abandoned cut-offs and meanders throughout the flood plains. Much of it is near the mouths of intermittent tributary drainage-ways.

The material is generally less than 3 feet above the normal level of the channels and is subject to frequent inundations. Its boundaries change with each slight rise of the stream. Even during normal flow, small areas are shifted about, enlarged, or removed by the changing current. Ordinarily, the deposits lie nearly level, but most of them drift when dry, and the surface is locally modified by small, wind-formed undulations.

The permanent water table is nearly everywhere within a 3- or 4-foot depth and during wet seasons may rise sufficiently to produce a marshy condition over small areas.

Riverwash is not a soil, but represents the first stage attained by alluvial deposits toward soil development. It contains practically no organic matter beyond the amount which accompanied the sediments when they were deposited. The color, which corresponds to that of the source material, is very light, except in localities where the sediments came largely from dark colored soils or formations. With the general accumulation of organic matter under conditions of undisturbed weathering, riverwash will ultimately develop into Sarpy soil.

Other Soil Series.--A number of soils series have been mapped in eastern Colorado which have not been sufficiently observed to describe separately or else it is believed they should be included with other soils. Those that have not been observed enough to describe are the Muner and Manvel series.

Those that probably should be combined with other series are: Las Animas - to be combined with Lincoln or Laurel. LaPorte loam and Penrose loam, shallow phase - to be combined with Sogn.

Soil series descriptions designated "after Hayes" are from descriptions of soil series in the plains, as prepared by Dr. Frank A. Hayes, Senior Soil Scientist, Bureau of Chemistry and Soils.