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SOIL SURVEY PILOT STUDY

POWDER RIVER AREA
MONTANA

UNITED STATES
EPARTMENT OF THE INTERIOR
EAU OF LAND MANAGEMENT
MILES CITY DISTRICT OFFICE
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PREFACE

The "Soil Survey Pilot Study" report is the result of a cooperative study by the Bureau of Land Management and the Soil Conservation Service. Objectives of the study were to acquaint some of the Bureau personnel with soil survey procedures, and to determine how such information could best be used in the Bureau program.

The writer participated in the cooperative survey from August 1961 to August 1963 as the Bureau of Land Management representative. Soil Survey methods used were those currently being employed by the Soil Conservation Service in conjunction with the National Cooperative Soil Survey effort.

It is hoped the report will not only be of value in summarizing the results of the pilot study, but also as a review and source of some basic soil survey principles. To some readers, the soils information may appear too elementary; however, since many persons in the Bureau of Land Management are not familiar with soil or soil surveys this approach to writing the report was thought to be desirable. The report is written in such a way that it contains not only information of local or state interest but also information which can be used Bureau wide.

The writer is not an experienced soil scientist. His principal contact with soil survey methods and interpretations has been during the Powder River Soil Survey. Therefore, some information and points of view may be limited or apply only locally and problems found elsewhere not touched upon. Most of the basic soils information has been extracted from many sources and rewritten from a range man's point of view.

A great deal of help and training given by John L. Parker, Soil Conservation Service soil scientist forms the background for this report.

Robert E. Adams
Range Conservationist

PART I

SOIL SURVEY PILOT STUDY

INTRODUCTION

Soil surveys are made cooperatively by federal and state government personnel. The federal agency having the primary responsibility for soil survey is the Soil Conservation Service. State agencies such as state colleges, universities and experiment stations and federal agencies such as the Bureau of Reclamation, Forest Service and the Bureau of Indian Affairs are cooperating in Soil Survey work. This joint effort, started in 1899, is now called the National Cooperative Soil Survey.

During 1960 the Director's office contacted the state directors relative to the desirability of a soil survey on Bureau administered lands in cooperation with the Soil Conservation Service. The SCS was actively surveying isolated tracts of Bureau administered lands along with the private lands that occured within designated survey areas; but they were not mapping large blocks of Bureau land. The Bureau had not participated up to this time in the field work of making a soil survey.

Early in 1961 the Director's office advised that it appeared desirable for the Bureau to enter into the National Cooperative Soil Survey, not only to fulfill our responsibility to the National Survey but also to fulfill a need for basic soils information as a tool for better resource management. The survey it was felt could best be accomplished through cooperative agreement with the Soil Conservation Service. Prior to entering into such an agreement it was determined that a pilot study would be initiated first. Dependent on the results of such studies a cooperative agreement between the two agencies would then be developed.

Pilot studies were initiated in three states, Nevada, New Mexico, and Montana. The Powder River Survey area in Montana was chosen because an active soil survey was in progress and due for completion soon and because the area contained substantial amounts of Bureau administered land where the results of the survey could be used effectively in the resource program.

As a party member the writer worked directly with the SCS in all phases of soil survey work on private and Bureau administered lands. Technical guidance came from the SCS party leader. Administrative supervision from the Miles City District Office.

Objectives of Study

Since the initiation of the pilot study a number of study objectives have been stated. These include:

1. To acquaint some of the Bureau personnel with soil survey procedures, and to determine how such information could be used in the Bureau program.
2. To determine the Bureau's needs regarding type of soil and vegetation correlation data required to make adequate range forage evaluations.
3. To attempt an evaluation of soil survey data for range classification and rating purposes.

In Montana the study emphasis was placed primarily on the first objectives, how soils information can be used in the Bureau program. The other two objectives are much narrower and concerned primarily with range. The use of soils data by lands, engineering and conservation personnel should also be considered.

History of Soil Surveys

Soil science as we know it today got its start about 1870 in Russia. A brilliant school of soil scientists developed under the leadership of V. V. Dokuchaeiv. These students observed that each kind of soil had a unique series of layers (what we now call horizons) from the surface down to the parent material at depths of 3 to 5 feet below the surface. They further noted these horizons resulted from powerful soil building forces acting on the geologic material below.

Thus the Russian scientists established for the first time what E. W. Hilgard had hinted at in his book of 1860, that soils are individual, natural bodies, each with its own morphology.

This concept of soils was as important in the progress of soil science as the development of knowledge of anatomy was to medicine. One could go directly to the soil itself and find its characteristics displayed in its own morphology and did not have to assume what the soil was.

Until 1914 when a textbook by Glinka, published in German, put forth these ideas, only hints of their far reaching results reached western Europe and America. While part of this new concept had been conceived by Hilgard in his early work and by G. N. Coffey, of the Bureau of Soils, and others, they had not reached it in a integrated form and their work received little attention until years later.

Perhaps the biggest single change in the approach to the development of soil classification in the United States occured in 1921. This approach first outlined by C. F. Marbut changed the emphasis from the geological nature of soils to the soil profile.

In spite of its importance the concept of the soil profile could be introduced into the American soil survey only after much field study. Enough field observations were necessary to demonstrate convincingly that the old approaches left many questions unanswered. Data already accumulated by the agricultural experiment stations and from soil surveys took on new meaning with this new and broader concept.

There were changes in approach to the American soil survey prior to 1921 and there have been further changes since that time. We know now that soils not only support living plants and microorganisms but these in turn have a great deal to do with the formation and behavior of soil. Soils are dynamic and ever changing. The soil system is not simply chemical and geologic but also physical and biologic.

With the new concepts of soil it became possible to develop a nationwide system of soil classification. From this information it makes possible the orderly planning of soil research and the interpretation of the results. Much of the work of mapping soils in this country is still to be done.

History of the Powder River Survey

The Powder River Survey was started in August 1954 by the Soil Conservation Service in cooperation with the Montana State Agricultural Experiment Station. The original survey area included all the land in the county except that in the Custer National Forest. In 1960 Custer

National Forest in Powder River County along with that part in the southwest corner of Rosebud County were included in the survey area.

Until the spring of 1960 very little block mapping had been done in the county, most of it had been mapped on a farm to farm basis by SCS soil scientists. The first block mapping was started by John L. Parker SCS party leader in April 1960. Under his leadership the descriptive legend was brought up to date. Previous soil mapping was checked for accuracy and conformity to the legend. William Berg of the Forest Service was assigned that same fall to map the National Forest lands.

During the summer of 1961 the Bureau of Land Management set up Powder River County as one of the three pilot study areas on soil survey. Actual field mapping of the soils were essentially completed by mid summer 1963.

Field reviews by SCS state office personnel to give technical supervision continued into the fall of 1963. Additional field reviews are expected during the spring and summer of 1964 before the survey is complete.

General Description

Location

Powder River County is located in the southeastern corner of the state of Montana. It is bounded on the north by Custer County, Montana, on the south by Wyoming, on the East by Carter County, Montana and bounded on the west by Big Horn and Rosebud Counties.

The entire county including a portion of Custer National Forest in the southeastern part of Rosebud county have been soil mapped. The survey area contains approximately 3,447 square miles, or 2,205,720 acres. It consists of 1,343,878 acres of privately owned land, 251,073 acres of land administered by the Bureau of Land Management, 445,043 acres of National Forest and 165,726 acres of State land.

Climate

The area is continental, with cold winters, warm summers and there is wide variation in seasonal precipitation. During a normal year about three-fourths of the annual precipitation will fall during the growing season, April to September. May and June are usually the wettest months of the year.

Areas of the lowest elevation (2800 ft.) receive the least amount of precipitation, about 12 inches, and those areas of higher elevation, (3900 ft. and above) receive more, about 17 to 20 inches a year on the average.

Annual temperature averages for the area range between 43.0 to 46.5 with difference in elevation having little or no influence on temperature.

The summers are warm with July maximums ranging in the upper 80's to the lower 90's. Winters are cold, but not nearly as cold as most other parts of Montana, cold days of 0°F. or colder occur less than 20 days a year.

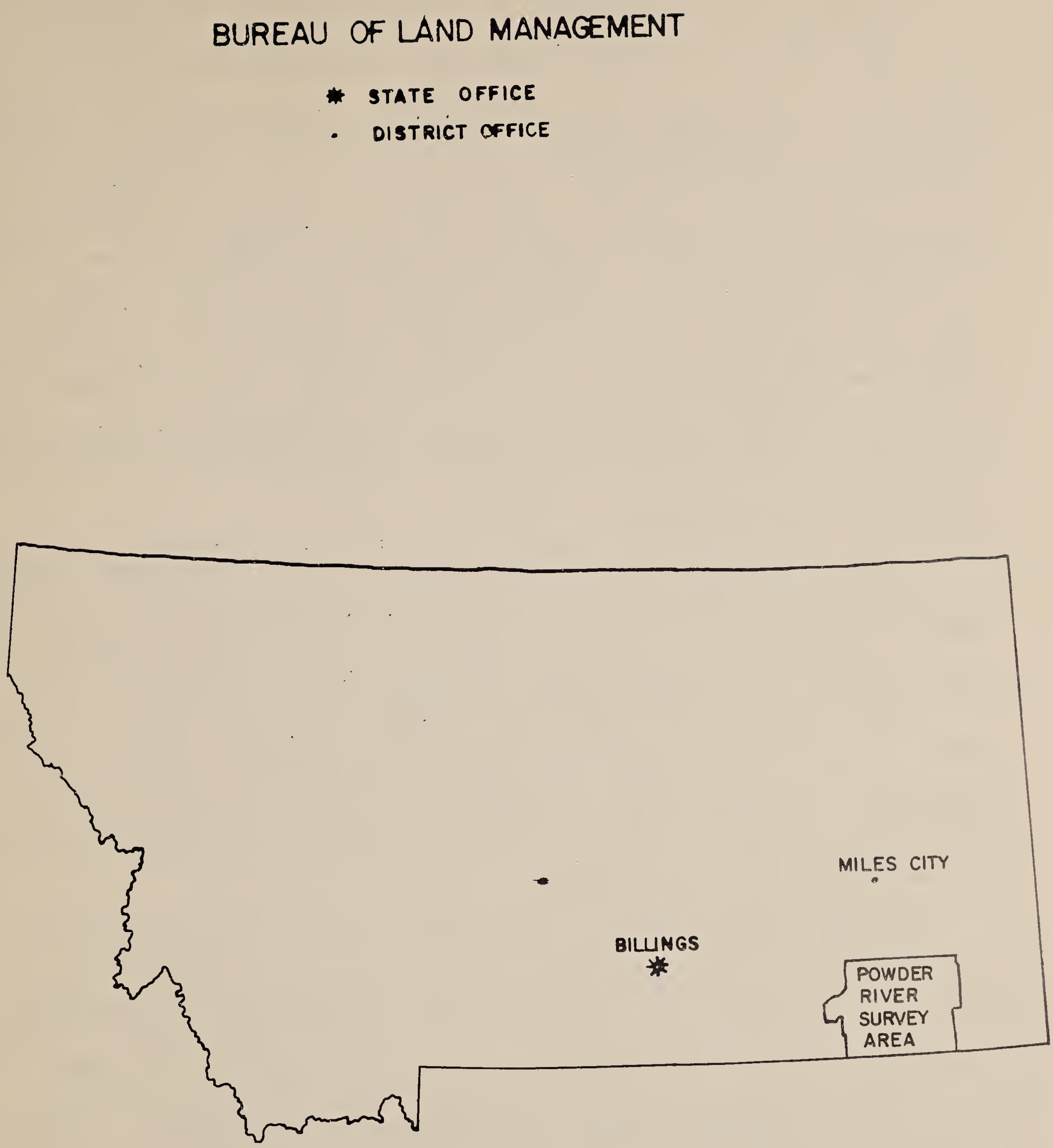
Tornados are extremely rare, only one has been reported in 35 years. Hail may occur in scattered areas every two or three years during June and July thunderstorms. Hail large enough to injure livestock or humans may occur about once every 20 or 30 years.

The average length of growing season, between spring and fall occurrences of 32°F., at Broadus is 128 days. Between 28°F. temperature occurrences the season averages 144 days, which affords a fairly long growing season for some of the more hardy crops. Broadus has nearly 6 months of winter in which the temperature can be expected not to fall below 24°F.

While the annual total rainfall gives the indication the area is semi-arid the 7 to 9 inches of precipitation that normally falls in the growing season enables dry land to produce good stands of native range in most years. Cultivated crops of winter wheat, barley, oats and alfalfa seed and hay are grown on small areas of irrigated and dry land along the river bottoms, stream terraces and the smooth upland benches and slopes.

Grazing of livestock accounts for about 90 percent of the land use and is the major source of agricultural income in the area. The winters on the average are not particularly stormy and winter feeding along the valleys is necessary only during short periods, every 3 or 4 years. Snowfall averages about 30 inches in the valleys where the livestock winter. Areas of higher elevation in the southwest quarter of the county may receive up to 100 inches of snow.

All seasons have considerable amount of sunshine, except for the rainy period of May and June and cloudy periods in November and December.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Physiography and Geology

The Powder River survey area is an upland plain in the Missouri River Basin. It is drained by tributaries of the Yellowstone River. Powder River is the main drainage tributary. Its headwaters are in the Big Horn Mountains of Wyoming. It and East Fork Creek, a tributary of of the Little Powder River, are the only perennial streams in the survey area. The southern and eastern portions of the survey area are drained by the Powder River and its tributaries. Tributaries of the Tongue River which flows northeastward through Rosebud County drains the northern and western parts of the area.

Powder River survey area is an unglaciated upland plain with relief common to the Missouri Plateau. It is a dissected pediment surface with only remnants of the upland surface remaining along the divides. Gully heads are actively cutting back into the ridges, tubular divides, and footslopes. Drainage sides are barren with narrow intervening valley bottoms 600 to 5000 feet in width.

The total relief of the area from the lowest point to the highest point is over 1500 feet. The lowest point in the area is in the north-western part of the county, (2768 feet above sea level). The highest point near the southwest corner has an elevation of 4305 feet. Most of the area lies between 3000 and 4000 feet above sea level.

The Powder River area is underlain by an estimated 11,000 feet of sedimentary rock strata, which is thickest in the southern portion of the county. Sedimentary rocks include limestones, dolomites, sandstone, and shales. These rocks, with the exception of those in the Fox Hills sandstone and Pierre shale, are of fresh water origin.

Tertiary rocks above the Roland Coal beds have been named the Wasatch formation. This formation is in a small area in the southwestern part of the County. It is the youngest formation and has a thickness of about 200 feet, occupying the ridge tops.

Over 80 percent of the Powder River area is underlain by the Fort Union formation. Red beds of clinker or "scoria" are often found on the tops of ridges and buttes. The Fort Union formation has an estimated thickness of about 1600 feet. The southern part of the county being the thickest, becomming thinner to the north, east and west. The base of the formation outcrops on the east side of the Little Powder River valley.

The Fort Union formation has been divided into two members, a Lower member and the Tongue River member. The Tongue River member is the upper 1200 feet of the Fort Union formation. The top of the Tongue River member is represented by thick deposits of reddish colored clinker on top of the buttes. These deposits were formed when the Roland Coal beds burned. The base of this member is the persistent buff-weathering sandstone above the Lower member.

The Lower member is about 375 feet thick and lies between the bottom of the Tongue River member and the top of the Hell Creek formation. This member has generally a darker color than the Tongue River member above. It consists primarily of somber gray to brownish gray calcareous thin bedded sandstones, shales and clays.

Other formations such as the Hell Creek and Fox Hills occupy small parts of the area, they occur east of the Little Powder River.

Soils of the Powder River Survey Area

The soils of the area are developed from the Fort Union, Hell Creek, Fox Hills and the Wasatch formations that are common to the Northern Great Plains. Parent materials are silty, clayey and sandy shales which have undergone changes by the soil forming factors to form the soil characteristics and patterns found in this area.

Soils are classified into orders, suborders, great soil group, family and series. Order is subdivided into (1) Zonal - those having distinct genetically related horizons with an A, B, C, sequence of horizons, (2) Interzonal - soils having more or less well developed soil characteristics that reflect a dominating influence of local factors of relief or of parent material over the normal influences of the climate and the vegetation on the soil forming processes. These soils may be geographically associated with two or more of the zonal groups of soils, (3) Azonal - A group of soils having little or no soil profile development. These for the most part are young soils and may be found in association with zonal and intrazonal soils.

Great Soil Groups

Great soil groups consist of many soil types whose profiles have fundamental characteristics in common. The tens of thousands of soil types in the United States can be classified into about 40 great soil groups. The Powder River Area has 9 of these great soil groups, they are: Alluvial soils, Brown soils, Chestnut soils, Regosols, Lithosols, Solonchak, solodized - Solonetz, Grumusols, and Gray Wooded soils.

Alluvial Soils - These soils are those developing from transported and relatively recently deposited alluvium (sand, mud and other sediments deposited on land by streams). There is little or no modification of the original materials by soil forming processes. Alluvial soils in this area are light in color and low in organic matter. They are generally high in lime and mineral plant nutrients. The alluvial soils occupy the level to nearly level and gently sloping soils along the major drainages.

Brown Soils - These soils are zonal soils developed under short grass, bunchgrass and shrub-vegetation type in a temperate to cool semi-arid climate. They have a brown surface horizon which grades to a light colored, weakly to strongly developed B horizon. Brown soils in the area are leached to an average depth of 14 inches to lime; whereas, the Alluvial soils may be calcareous from the surface down. Alluvial soils also differ in being lighter colored and lacking the genetic A, B, and C horizons found in Brown soils. The Brown soils vary considerable in texture, from a fine sandy loam to a clay. They also vary a great deal in thickness and depth to weathered materials.

Chestnut Soils - They are a zonal group of soils with a dark-brown surface horizon, which grades into a lighter colored horizon beneath. The lime has been leached to depths of 1 to 4 feet deep. Chestnut soils are developed under mixed tall and short grass in temperate to cool and subhimid to semi-arid climates. Chestnut soils occur generally in regions a little more moist than those having Brown soils. Locally however, the Chestnut soils occur in association with Brown soils in positions receiving more moisture because of aspect or elevation. In this area Chestnut soils differ from the Brown soils in having a darker colored A horizon and being about 8 inches deeper to lime, and lack the strong development found in some of the Brown soils.

Regosols - An azonal group of soils without definite genetic horizons developing from unconsolidated or soft mineral deposits.

Lithosols - A Lithosol is a soil having little or no evidence of soil development consisting mainly of a partly weathered mass of either softly consolidated or hard rock material. Lithosols differ from the Regosols in having an incomplete solum (the upper part of the soil profile above the parent material) consisting of imperfectly weathered mass of hard rock or rock fragments. It may be a soft bedded material where root penetration is stopped.

Solonchak - An intrazonal group of soils with high concentrations of such soluble salts as sodium and calcium. They lack either prismatic or blocky structure; they are sometimes called structurless but they really have a soft fine granular structure. Solonchak soils occur mostly in subhumid or semiarid climates developed under salt loving plants. It occurs in intricate pattern with zonal and other intrazonal soils in the area. A good example of a Solonchak soil found in this area is the Bone silty clay loam which appears as barren areas or panspots in the landscape.

Solodized - Solonetz - An intrazonal group of soils with well developed structure. They have a friable, light colored, leached, A horizon with a darker colored, prismatic, B horizon. The surface layer may leach down through into the lower horizons coating the columns with bleached sand grains. When drainage improves or a gradual lowering of the water table occurs a soil may go from a sodium - Solenchak to a solodized-Solonetz. A well developed solodized - Solonetz may release calcium and magnesium from the soil minerals by further weathering in place and be brought up by the native vegetation, and replace most of the sodium. Thus a solodized - Solonetz may have lost most of its exchangeable sodium and be a fairly high producing soil. Frequently the leached A horizon is blown away during periods of extreme drought, exposing the hard clay B horizon in shallow pits called slick-spots or scabby spots. These soils are called truncated solodized-Solonetz. Large areas of these soils occur in regions of the northern Great Plains.

After truncation, the truncated solidized-Solonetz may go through another stage of being a solodized-Solonetz. Gradually however, with improved drainage and the invasion of the normal native vegetation, the soil will again become saturated mainly with calcium or calcium and magnesium and will change to a zonal soil of the region, for example, Chestnut or Brown.

Solodized-Solonetz are found on the older alluvial flood plains, stream terraces and gently to strongly sloping footslopes.

Gray Wooded Soils - These are moderately deep soils (30 to 35") with a light to dark grayish brown color. Locally these soils are found on some north and east facing slopes under forest type vegetation. They are formed over weathered sandstone and porcelainite shale or "scoria".

Grumusols - Soils in this great soil group are those developing in materials high in montmorillinite clay. They swell when moistened and crack deeply when dry. The shrinking, cracking and shearing make them very unstable. They may be found on flood plains and the uplands.

Soil Series

A soil series is a group of soils individuals having soil horizons similar in differentiating characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Soil texture of the surface soil will vary within the series.

The soil series itself is seldom used as a mapping unit. There usually is not enough homogeneity in such features as slope, stoniness, and amount of erosion; and rarely does it occur in areas large enough to be mapped out. The series name used as part of a mapping unit name is the key to the majority of the soils found in the area. The series brings units of mapping together in an organized manner to help us remember soil properties and the relationships among soils.

Soil individuals are real things, but series are conceptual. A series, cannot be seen or touched, although the soil individuals that we identify as parts of a series may be seen and touched.

Soil series names are used in various ways and may result in some confusion. The Bainville series, for example, may be spoken of as a taxonomic class that includes all the soil individuals within the defined limits of Bainville. Another way the series name is used is when we examine a soil profile and say, "this is Bainville", meaning that the properties we find in that particular soil profile are those we ascribe to Bainville. Bainville may also be used as a name for an area shown on a soil map if the Bainville series can be identified in 85 percent or more of the area. The other 15 percent or less of the mapping unit is inclusions of other soil series. Bainville may also appear in other mapping units with different series names as an inclusion. These three uses of the series name Bainville are all proper.

Soil series are differentiated mainly on the basis of observable significant variations in the morphological properties of the soil profile. Such properties include the kind, thickness, and arrangement of horizons, their color, texture, structure and other properties. A different series may be recognized if there is a significant difference in any one of these properties in any one horizon. Usually however, these properties are genetically related and seldom does one property change without others changing.

Relief is one important genetic factor partly responsible for the characteristics of the profile, and since shape is a property of the soil body, each soil series has a defined range in slope. Some soil series have a wide range in slope, in others it is quite narrow.

Hard and fast rules covering the acceptable variation in properties within the range of a soil series may be difficult to make. No two profiles are identical, some variation in every property must be allowed. Otherwise every soil profile would be a separate series.

Judgement plays an important part in weighing the magnitude of differences in properties that are observed, measured, or inferred and in testing the probable significance of those differences to soil genesis and to soil behavior.

Features other than soil properties have inappropriately been used in the past as a series differentia. Physiographic position, and the occurence in geographic regions have been the basis for series differentiation. Although these differentiae are not features of the soil, sometimes they are directly correlated with the distribution of certain soils.

Soil series are named for the place or area where the soil is first defined, such as Havre, Bainville, Midway and Glendive. A nation-wide listing of series names is available to prevent duplication of series names.

In the Powder River area there are about 50 different series. The names of which are subject to change, until after the final field review of the survey area. Most of the series found in this area have already been defined in other areas of the northern Great Plains. The same soil series here will be similar to those with possibly local variation.

The Soil Type

The soil type is a subdivision of the series based on the texture of the plow layer of the soil. In the natural system of classification the soil type is the lowest and most nearly homogenous unit. There may be defined variations in such things as slope, stoniness and degree of erosion but to remain within the same type, soils cannot vary more than the defined limits. These variations are called phases.

Soil Associations

The soil association is a group of defined and named taxonomic soil units, regularly associated geographically in a defined proportional pattern.

AREA I

This area is along the eastern side of the county. The soils consist mainly of loam, silt loam, and sandy loam textures. It is an area of steep, shale exposed buttes and drainageways with smooth rounded hills, tubular divides and ridges. Brown soils occupying the stream terraces, smooth footslopes and draws are used for cultivated crops. Large areas of solodized-Solonetz occur in the northern part of the area.

The soils in this area are developed over the Fox Hills Formation, a sandy formation.

AREA II

Approximately one-third of the survey area is in this soil association. Soils range in texture from a silt loam to silty clay loam and are developed from soft sandstone, silty and clayey shales of the Fort Union Formation. This area is a steep (8-35 percent) broken dissected upland with interspersed smooth rolling convex hills. Solodized-Solonetz occupy small areas in the landscape. Broken slopes, with widely separated ledges of sandstone a few feet thick, and with nearly barren shale exposures dominate the area. Soils in the bottom lands are mainly Brown zonal soils and are used for cultivated crops.

AREA III

This association includes the flood plains, stream terraces and valley slopes of the larger streams and rivers. Most of the valleys are 1/4 to 1 mile wide. Soils are predominantly alluvial with other soils found on the stream terraces. The major cultivated area in the county is in this area.

AREA IV

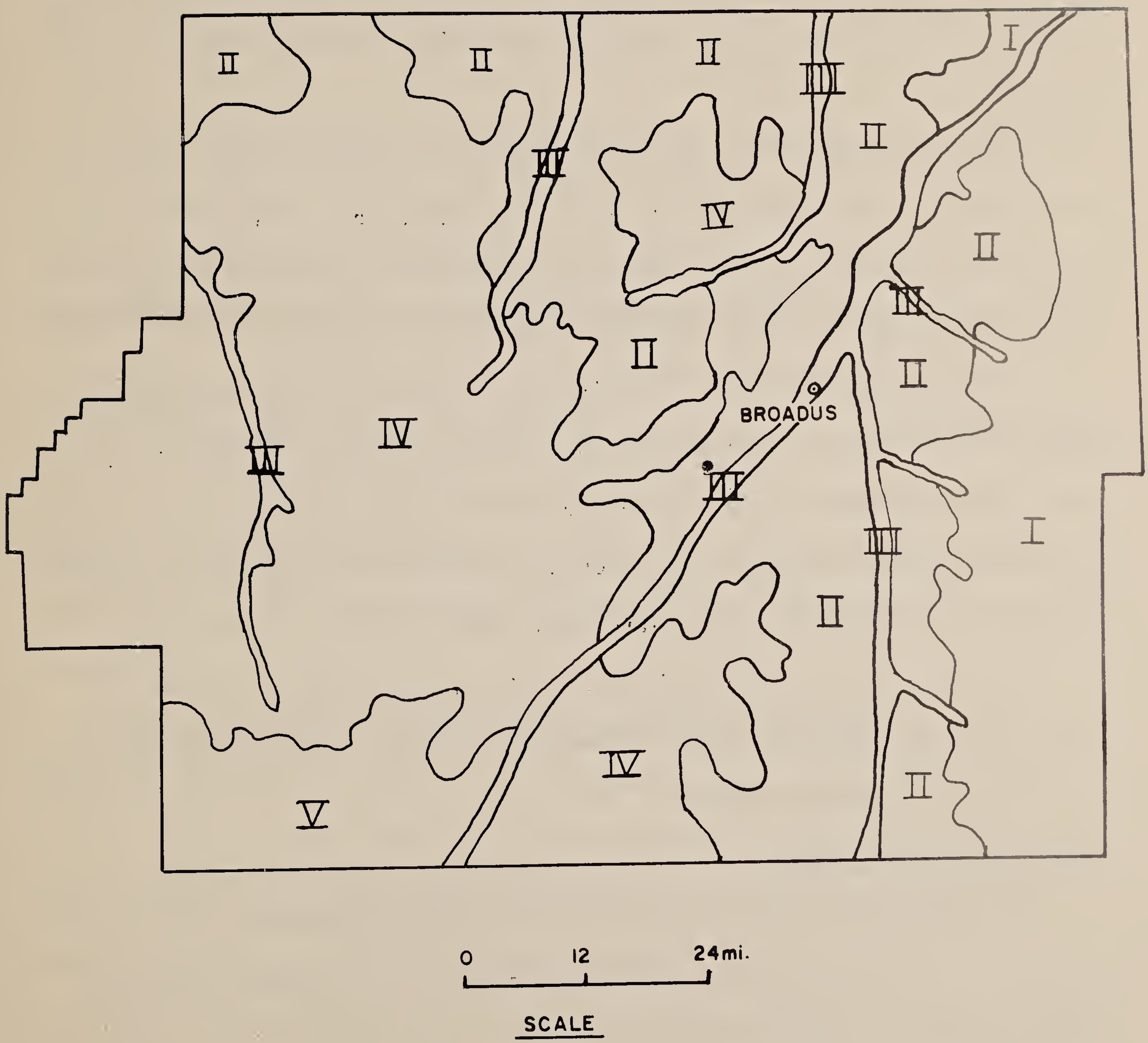
This area is located primarily on the west side of the county. It is characterized by having steep sided shale exposed slopes, narrow divides, rounded buttes and red capped tree covered hills. Red coloring comes from the burned coal beds of the Tongue River member of the Fort Union formation. Soils developing from these red beds have a reddish hue.

Areas of Brown and Chestnut soils are also found in the association, along with small areas of Grey Wooded soils. There is wide variation of soil and topography in this area.

AREA V

This soil association occurs only in the southwest corner of the survey area. It consists of steep sided, narrow topped remnants, and smooth rounded hills of clay and clay loam soils. Soils of the valley bottoms and stream terraces and smooth upland footslopes are common to the survey area and are used for cultivated crops.

POWDER RIVER SURVEY AREA
SOIL ASSOCIATION MAP



PART II

SOIL SURVEY

What is a Soil Survey

A soil survey includes among other things the finding out which properties of the soil are important. Soils are classified into defined and described units. Boundaries are located and plotted on the map. Interpretations are made on the adaptability of soils to various crops, grasses and trees, and their productivity under different management systems. A soil survey also includes preparing and publishing the maps and report.

Soils are classified and named somewhat the same as plants are. Just as plants are identified by such distinguishable characteristics as rhizomes, spiklets, etc., soils are identified by texture, kinds and depths of horizons, structure, color and other features.

The soil map is a tool for selecting a system of soil management. There are many uses of soils maps by different people. Generally, however, they are used for the purpose of identifying the soil or as a basis for applying the results of research and experience to individual fields. As people gain confidence in soils maps there will be increased use.

No two areas of the same kind of soil are identical but like two pine trees the similarity is so close they should respond to the same practices in a similar manner.

Plans for a Soil Survey

A survey work plan is set up by the cooperating agencies for the purpose of a clear understanding of the work to be performed and other contributions of each participating agency. The work plan will show by name if possible the survey party leader who will be responsible for the mapping and the writing of the survey report. The soil survey work plan is not legally binding upon the agencies who sign it.

<u>The Initial Review</u>

Following the preparation of the survey work plan an experienced soil scientist (the state soil scientist or appropriate soil correlator), usually from the State Soil Conservation Service Office, takes the leadership. They and the local survey party chief who will be in charge of the mapping and representatives of each of the cooperating agencies travel over the area making preliminary field soil studies. The review party studies the soils and the landscapes. They will identify established series and record the local peculiar variations. Any new proposed series will be studied in considerable detail and profile descriptions made, noting locations, slope, vegetation and other relevant information. A few mapping units can be studied and described, especially complexes and associations. These are mapping units which contain two or more similar or contrasting soils that occur together in a more or less regular pattern. They are so intricately associated geographically that they cannot be separated by boundaries at the scale used. Other mapping units will be discussed and a list made of those actually identified or known to occur in the area.

After the initial review has been made the ground work for the descriptive legend has been laid. This is the most important function of the initial review. Too much stress cannot be placed on a good initial review because the report and legend prepared at that time becomes the chief guide for the direction of the survey.

The Descriptive Legend

The survey party leader starts writing on the descriptive legend soon after the initial review. A good descriptive soil legend is the most important tool of the survey. The degree of accuracy and quality of the survey will reflect the quality of the descriptive legend.

What is the descriptive legend? The best way to describe the descriptive legend is to tell what is in it.

It contains some general information about the area, the location and history, relief and drainage, a general soil association map, and a narrative on the geology of the area. The descriptive legend contains an index listing the different mapping units in each soil series. There is usually an alphabetized and numerical listing of all mapping units found in the area. These lists may contain some interpretive groupings as range site and capability class.

Probably the most important part of the descriptive legend are the descriptions of the soil series and their respective mapping units. A series description cannot be written from a single profile examination, a number of profiles need to be observed to get a representative description and a range in characteristics. Series descriptions can be broken down into about four essential parts:

1. A lead sentence which includes the Great Soil Group, natural drainage, texture, and kind of parent material, followed by the distinguishing and identifying characteristics and typical horizon sequence.
2. Comparison between similar and associated soil series.

3. Detailed profile description that is modal for the survey area, describing each genetic horizon in considerable detail.

4. Range in characteristics giving the defined limits for color, texture, structure, reaction and other characteristics. The soil scientist groups soil individuals having similar characteristics, within the limits of variation, into taxonomic units. If a soil individual does not fall within these limits it is a different taxonomic unit. Under certain circumstances, however, the range in characteristics or limits of variation must be expanded to include a soil, or narrowed to exclude a soil.

It is difficult to set clear, precise, unchanging limits in the classification system. As in most fields of systematic classification there are those that "lump" and those that "split". As defined, mapping units are kinds and proportions of taxonomic units. A soil series is a taxonomic unit. A soil mapping unit that bears the name of a taxonomic unit consists of this defined unit and sometimes also small inclusions of other soils that must be included because of the limitations imposed by the scale of mapping and the number of points that can be examined. There can be up to 15 percent inclusions of other soils without changing it to a complex mapping unit.

A soil complex is a mapping unit which consists of two or more different kinds of soil individuals or taxonomic units. These may be similar or contrasting but occur together in a more or less regular pattern and are so intimately associated geographically that they cannot be separated by boundaries at the scale used. Two or more soil individuals that are not regularly associated geographically may also be mapped as a single unit. The objective of the survey or the expense may not warrant the separation of units where differences are slight.

Soil Mapping

Soil scientists with their knowledge of the relationship of landscape features, climate, parent material, relief, and vegetation to soil properties make detailed soil maps. Aerial photographs are used as a base for plotting the soil boundaries. The scientist goes over the land and digs as many holes as necessary to determine and evaluate the important characteristics of the profile. He identifies the kind of soil, locates and plots its boundaries on aerial photographs and places the mapping unit symbol on the map. The amount of time spent examining the boundary on each unit will depend on the detail required of the survey. In making a high intensity detailed map many soil examinations are necessary to determine where the boundary lies between two soils. Medium intensity surveys require fewer examinations of the soil and low intensity fewer yet.

No two soils examined in the field are exactly the same. Those soils that are not significantly different in soil genesis and soil use are placed together in the same mapping unit.

Many soil mapping units merge into one another through a transitional belt which may vary in width from only a few yards wide to many yards wide. An inexperienced soil scientist may set up another mapping unit for this transitional soil and further confuse things by having to place two lines on the map instead of just one boundary line.

Additional information about the landscape, such as drainage pattern, position of rock outcrops, lakes, ponds, roads, wells, springs, and the like are also placed on the map by the soil scientist.

All stages of the soil mapping clear through to the writing of the soils report are checked by supervisors. During the course of the field mapping many progress field reviews are held to check the mapping and help discover and correct errors in classification and interpretations.

When the field work is essentially complete a final field review is conducted by the senior soil correlator, state soil scientist of the S.C.S. and representatives of cooperating agencies. It is a systematic and thorough appraisal of the entire survey. The consistency and accuracy of the mapping, cartographic detail, descriptive legend, interpretations and related material are reviewed.

Correlation Samples

Classification of soil is based upon a set of reference points. The primary reference point of soil classification and mapping is the correlation sample and the profile description. These samples are representative of the central concept of the series or taxonomic unit.

Correlation samples are small loose or fragmental soil samples of each genetic horizon. A complete and accurately described profile description accompanies each sample.

In correlation, decisions are made as to either identifying the soil as similar to one already established elsewhere, or naming the soil as a new taxonomic unit. Names are thus assigned to the mapping units to be shown on the published maps. These names will be consistent with the general system of classification and nomenclature used elsewhere in the state, region and nation.

Some Interpretations Made of Soil Surveys

1. Brief descriptions of the mapping units made for people

other than soil scientists. These descriptions are understandable by people not familiar with the jargon of soil scientists.

2. Interpretive groupings for different purposes such as:
   a. Capability groups, the class, subclass and units.
   b. Range sites or management units.
   c. Woodland and windbreak site groups.
   d. Wind erodibility groups.
   e. Wildlife suitability.
3. Estimated yields of principal crops, under different levels of management, for most soils suitable for cultivated crops.
4. Interpretation for engineering purposes.
   a. Properties of the soil that affect their use for engineering purposes. For example, soil depth, permeability, dispersion, shrink-swell potential, etc.
   b. Suitability of soils for engineering practices, such as reservoirs, land levling, dikes and waterspreaders, road subgrade, road fill, etc.

It must be realized, however, the mapping and descriptive reports are somewhat generalized and should be used only in planning. A more detailed study of in-place conditions of the soil must be made at the proposed construction site.

Soil Survey Report

Plans for publication of soil survey reports are a part of the work plan made at the start of the survey. Any significant changes in the original plans are worked out in advance of the survey completion by the cooperating agencies.

The soil scientist designated as party leader has the responsibility for writing the soil survey report. He is also responsible for keeping the descriptive legend and the soils handbook current. The soil handbook which includes the descriptive legend should furnish all the information necessary for the soil survey report. The primary purpose of the soil handbook is to assemble in one place all pertinent data about the soils of the area including their use and management, for all purposes. A good soils handbook of the survey area should enable any soil scientist to write the soil survey report.

The scale of the published maps is determined largely by the amount of cartographic detail to be shown on the map and its probable use. Most detailed maps of high and medium intensity are published at a scale of 1:20,000 or 3.168 inches per mile. A larger scale of 1:15,840 or 4.0 inches per mile may be selected if it makes the maps significantly more useful. Surveys of low intensity mapping may be published at a scale of 1:31,680 or 2.0 miles per inch, and in certain instances a smaller scale.

Published soil maps are ordinarily printed on a photo-mosaic base. Cultural and drainage features are printed on black, and the soil boundaries and symbols in red. Most sheets are 17 by 11 inches in size, with printing on both sides of the paper.

The author of the soil survey report, if an employee of the SCS, sends the completed manuscript to the State soil scientist. The State soil scientist arranges for reviews by representatives of the state agricultural experiment station and other cooperating agencies to insure scientific and technical adequacy.

Specific sections of the report dealing with engineering, agronomy, woodland, range and wildlife are reviewed for technical adequacy by SCS specialists in these fields. After these reviews are completed the manuscript is forwarded to the principal soil correlator in Lincoln, Nebraska for his review. After being reviewed there and approved, it is forwarded to the office of Soil Survey Reports at Beltsville, Maryland where it is edited and prepared for final publication. Edited copies are returned for final proof reading and review by the author, cooperating agencies, and by the soil correlator before the manuscript is cleared for printing.

If the author is not an SCS employee, reviews and routing of manuscripts are arranged by the cooperating agencies.

The SCS orders the number of copies of the soil report, complete with maps, that it estimates will be needed to fill requests from farmers, ranchers and others. Each Representative in Congress from the district where the survey is located may order up to 1000 copies, and each U. S. Senator from the state may order up to 250 copies. The cooperating agencies that signed the soil survey work plan may each receive 50 free copies. (Soils Memorandum SCS-25 Revised). Others may be purchased at the cost of printing.

It takes from 3 to 4 years after the soil mapping has been completed before the report is published. Photographic copies of the unpublished maps may be purchased through the SCS.

Soil surveys and reports have been made and published by various state and federal agencies. Prior to 1923 the Bureau of Soils was responsible for publishing soil surveys. From 1923 to 1931 the Bureau of Chemistry and Soils was responsible for surveys. Reports and maps from 1932 to 1952 were published by the Bureau of Plant Industry. Reports after November 1952 were published by the Soil Conservation Service.

PART III

SOIL CLASSIFICATION

Genesis and Morphology of Soils

Soil formation is the result of five major factors, climate, living organisms, parent rocks, topography and time. They control the weathering of rocks and the gains, losses, and alterations throughout the regolith (the unconsolidated mantle of weathered rock and soil material on the earth's surface), including the soil profile.

Soil formation proceeds in steps and stages, none of which is distinct. It is not possible to tell where one step in soil formation stops and the next starts.

Temperature and rainfall govern the rates of weathering of rocks and the decomposition of minerals. They also influence leaching and the movement of soil material from one place to another within the soil profile. Climate indirectly affects the kinds of plants and animals that can thrive in a region. In turn, these living organisms are of major importance in differentiating the soil horizons.

Climate is so important in soil formation that broad soil regions of the world tend to correspond closely with the distribution of climates. The soil and climatic regions, however, are not identical because there are five factors, rather than one, important in soil formation.

Plants, animals, insects, bacteria, fungi and other living organisms are important to horizon differentiation and less important to the accumulation of soil parent materials. Living organisms are responsible for gains or losses in plant nutrients, gains in organic matter and nitrogen and changes in soil structure and porosity. Plants and animals also mix horizons and thus retard their differentiation.

Parent rock is sometimes called a passive factor in soil formation. The parent rock is weathered to form soil parent materials which are changed further as horizons develop in the soil profile. The composition and structure of the rock strongly influences the rate at which it will weather. It also influences the products of that weathering. Some rocks such as quartz are highly resistant to weathering. Small quartz grains may dissolve very slowly, but no plant nutrients are released.

Topography, or the relief of the land influences soil formation primarily through its effects upon drainage runoff and erosion, and secondly through variations in exposure to the sun and wind and air drainage. Soil profiles on the average are shallower on steep slopes than those on gentle slopes. Low flat slopes often mean the soil has had extra water. Extra water means higher organic matter content in the A horizon. Topography thus influences the moisture in the soil and the erosion from its surface.

Time is required for soil formation - how much depends on where the process must start. Freshly exposed limestone would require considerable amount of time to develop into a soil. Millions of years may pass before the parent materials have accumulated and horizons have been formed. An A horizon may be formed in fresh regolith within just a few decades, in other soils it may take 2,000 years or 20,000 years to develop a B horizon.

None of the five factors of soil formation are uniform over the face of the earth. There are wide variations in all of them. As a result there are hundreds of thousands of different local combinations of the factors of soil formation. Thus, there are many differences in the soil itself. Differences are local and regional. Soil types in the United States probably number in the tens of thousands.

These soil types are not scattered about without rhyme or reason as they may seem. Each soil occurs in a definite geographic area and in certain patterns with others. A soil type commonly called a phase is a three dimensional body, it has length, width, and depth but is seldom large. Most are a few acres in size. Each soil type occurs as a number of distinct bodies which may be found over parts of several states or restricted to a small part of one. Each soil type can be defined by a profile description of the typical soil. Allowable deviations that may be found varying from that profile are given. Other features such as relief, drainage, vegetation and stoniness are described. Every soil type has neighbors, it never occurs by itself. Wherever it is found the same soil types tend to be associated with it forming a characteristic pattern. The soil bodies or soil types fit together like a puzzle and usually grade into one another without sharp boundaries between them. Associated soil types rarely are found to have a sharp clear boundary between them. Differences among the associated soils may be large or small but are generally smaller than regional soil differences. Climate and living organisms usually account for the regional soil differences; however, differences may reflect dissimilar topography, ages of land surfaces, or character of parent rocks.

Soil Classification Systems

There can be no true classification system since they are all devised by men to suit their purposes. Each system has some drawbacks. The best system is the one that will best serve the purpose or purposes for which it was made. Classification will change as our knowledge expands and our needs change. Classification is merely the arranging of objects into compartments or categories.

Many technical and natural systems of classification are possible. A technical system, sometimes called and interpretive classification is one that arranges soils into classes to permit fairly specific statements about the soil. A natural or taxonomic system shows the genetic and morphologic relationships between soils.

Taxonomic Systems

U. S. Department of Agriculture Classification System

The first natural system was by a Russian, V. V. Dokuchaeiv in 1886, later revised in 1900. Between 1912 and 1938 various concepts of soil classification were developed in the United States. Each system contained serious defects which limited their usefulness.

The most recent U. S. classification system was published in 1938, and revised in 1949. This is the system presently being used in soil survey work. All soils in this system are first divided into three major categories, zonal, intrazonal and azonal soils (definitions for these terms were given in the section on Soils of the Powder River Survey Area). These three categories are further divided into suborders, great soil groups, families and series.

As common with almost all natural systems, this system also has several major defects. One of the major defects is the vague definitions of the classes, resulting in different interpretations of the meanings. Another defect is that the system is primarily based on the properties of virgin soil in the natural landscape. The cultivated soils have either been ignored or classified on the basis of what the virgin soil was presumed to have been.

Man may have a significant influence on the soil by (1) changing one or more of the soil forming factors, (2) changing the soil color, and (3) erosion may remove horizons or plowing may mix horizons. Soils are not static. A workable system of soil classification must be able to provide for changes in the soil itself.

Soil Classification - A Comprehensive System (7th Approximation)

With these defects in mind a new system was started in 1951 by the Soil Survey Staff of the Soil Conservation Service. It was believed that the most useful system would be a comprehensive one accommodating all soils in the world and showing their relationship with each other. It was decided that a workable system could not be developed without the experience of a great many soil scientists, world wide. The number would have been too large and unwieldy to work effectively as a group. It was further decided to develop a series of approximations, testing each one by circulating it among soil scientists to discover its defects and thus gradually improve the system.

Each succeeding approximation has had wider circulation to an ever increasing number of soil scientists.

The system is now in its 7th approximation and it is hoped the last one before the system is ready for adoption and use by the Department of Agriculture, and other federal and state agencies cooperating in soil surveys.

A thorough understanding of the Soil Survey Manual is necessary to understand the new system. Those whose knowledge of the soil is limited will find much of the 7th approximation meaningless and confusing.

Some of the main characteristics of the new soil classification scheme and differences from the old scheme are:

1. All classes or categories are defined in terms of the soil properties. The difference between this and previous classification is the nature of the definitions. Properties that can be

measured or estimated in the field have been given emphasis.

2. Definitions are based on the properties of the soil that exist today - not the properties that we believe the virgin soil had in the past or will have in the future. Changes in the classification of a soil as a result of a single plowing or the cultivation for a few generations are undesirable, as they conceal the relations between the virgin soils that may remain and the arable soils. Thus, the nature of the B horizon is given more weight than the nature of the A horizon.

3. A systematic nomenclature is used in the new system using coined words derived from Greek and Latin. These words indicate something of the properties of the soils. This should make the classes easily remembered by soil scientists.

4. There is a change in categories from the old system now in use. A new class, the subgroup has been introduced to facilitate the showing of relationships between soils that may have properties of more than one great group.

5. The categories in the new system of soil classification are: order, suborder, great group, subgroup, family and series.

6. The soil type, based on the texture of the plow layer, is not being retained as a category of the classification system. Previously the soil type has been the lowest category in all the American soil classification systems.

Interpretive Systems

The Unified, AASHO, and the land capability classifications are three examples of technical or interpretive systems of soil classification. Many different systems or grouping for various purposes and groups of people are possible. Soil classification is tied closely with interpretation. None of these classifications are used in soil survey field mapping.

Unified Soil Classification System

This system is a modification of the original Casagrande Airfield Classification developed by Dr. Arthur Casagrande for the Corps of Engineers during World War II. The Corps of Engineers in cooperation with the Bureau of Reclamation expanded and revised the system so that it also applied to embankments and foundations, as well as roads and airfields. The system is based on those characteristics of the soil which indicate how it will behave as a construction material. This Classification system is the one generally used by Bureau of Land Management engineers in the design and construction control of detention and diversion type earth structures.

Soil identification is based upon the following properties:

1. The percentage of gravel, sand and fines.
2. Shape of the grain size distribution curve.
3. Plasticity and compressibility curve.

The soils are divided into three major divisions:

1. Coarse grained soils having 50 percent or less material passing the No. 200 sieve.
2. Fine grained soils which contain 50 percent or more material passing the No. 200 sieve.
3. Highly organic soils.

These classes are further subdivided to be more specific about a soil. With experience fairly accurate field classification of soils can be made using this system. Some of the physical properties of groups in this classification system may be found in the section on Engineering Interpretations.

A Chart showing a more complete picture of the classification system will be found in the Appendix.

AASHO Classification System

This is the American Association of State Highway Officials system of soil classification. This system is most widely known and used in highway and road planning. The Bureau of Land Management may find use for this classification system in access road planning. In the soil survey reports, soils are often classified by this system.

Originally devised in 1931 by the Public Roads Administration it was revised and changed by other groups until 1945 when it became a standard of AASHO.

Soils are grouped into seven basic classes, based on load-carrying capacity.

Land Capability Classification

Land capability classification is limited primarily to agricultural uses. Soils are grouped into capability classes, subclasses and units. These interpretive soil groupings are made to help the user see what limitations or problems will be encountered in management. This system will have wide application in Bureau of Land Management land classification activities.

Developed primarily by the Soil Conservation Service there are eight capability classes in the system. These are shown as Roman numerals I through VIII. Classes I through IV are suitable for cultivated crops. Classes V through VIII are generally suited to range, wildlife and watershed. Under special circumstances, these soils may be cultivated.

Several kinds of soil often occur in the same capability class so they are subdivided into subclasses. Subclasses are problems or limitations encountered in soil management. Four kinds of problems are recognized, and are indicated by the symbols: (e) erosion and runoff; (w) wetness and drainage; (s) root zone and tillage limitations, such as shallowness, stoniness, droughtiness, and salinity; and (c) climatic limitations. All capability classes except I may have one or a combination of these subclasses.

Land capability units are the most detailed and specific of the capability classification. Soils that can be used the same way and give about the same crop yield are placed in the same capability unit.

Capability Classes

I. Very good land from all points of view. It is level or nearly level and does not wash or blow readily. The soil is deep and easily worked. It has good water holding capacity and is fairly well supplied with plant food. Land in this group can be used safely in almost any way selected.

II. Land in this group has a slight erosion hazard and will require conservation treatment to keep it productive if cultivated. Limitations for this group are not great or are the conservation treatments difficult. Limitations in class II may include singly or in combination the effects of (1) gentle slope, (2) moderate susceptibility to wind or water erosion, (3) less than ideal soil depth, (4) somewhat unfavorable soil structure and workability, (5) slight to moderate salinity or alkali, easily corrected but likely to recur, (6) occasional damaging overflow, (7) wetness correctable by drainage but existing permanently as a moderate limitation, (8) slight climatic limitations on soil use and management.

III. This land has more serious limitations that restrict its use or requires more careful management than class II. Limitations restrict the amount of clean cultivation; timing of planting, tillage, harvesting and choice of crops; or a combination of these items. These limitations may be the result of natural restrictions or by the way the land has been used. The limitations may result from the effects of one or more of the following: (1) moderately steep slopes, (2) high susceptibility to water or wind erosion or severe adverse effects of past erosion, (3) frequent overflow accompanied by some crop damage, (4) very slow permeability of the subsoil, (5) drainage problems, (6) shallow depths to bedrock, hardpan, fragipan or claypan that limits the rooting zone and water storage, (7) low moisture-holding capacity, (8) low fertility not easily corrected, (9) moderate salinity or alkali or (10) moderate climatic limitations.

IV. Class IV land has serious restrictions that limit the choice of use or require very careful management. The land may be well suited to only two or three common crops. The amount of harvest may be low in relation to input over a long period of time. Years favorable for cultivated crops are limited. These soils are limited by one or more of the following features: (1) steep slopes, (2) severe susceptibility to water or wind erosion, (3) severe effects of past erosion, (4) shallow soils (5) low moisture holding capacity, (6) frequent overflows accompanied by severe crop damage, (7) excessive wetness with continuing hazard of waterlogging after drainage, (8) severe salinity or alkali or (9) moderately adverse climate.

In semiarid regions soils in class IV may produce good yields of adapted crops during years of above average rainfall. Low yields during periods of average rainfall, and crop failure during years of below average rainfall. Special treatment is needed to conserve moisture, prevent soil blowing and maintain soil productivity.

V. Soils in this class have little or no erosion hazard. Soils in this class are nearly level, often wet, or frequently overflowed, stony, or have limitations that are impractical to remove, or combinations of these limitations. These soils are generally unsuited to cultivation. Their use is normally limited to pasture, range, woodland or wildlife.

VI. Soils in this group have pronounced features such as steep slopes, severely eroded, stony, shallow, wet conditions or low water-holding capacity. Severe limitations as these make them generally unsuitable for cultivation. They can be cultivated if intensive management is used. Grass species can be seeded for pasture and range. Class VI land is suited to range or wildlife.

VII. These lands are restricted to grazing, woodland, or wildlife. Land is not suited to cultivation and careful management is required for grazing or forestry. It is generally impractical to apply such practices as seeding and water control measures to the land.

VIII. Land in this class has severe limitations that limit their use to recreation, wildlife, watershed, or aesthetic purposes. Examples of land in this class are badlands, rock outcrop, sandy beaches or dunes, river wash and barren lands.

Terms describing the limitations are necessarily quite general. It depends upon the geographical area in which the capability class is used. For example, steep slopes may mean those of 15% some places and 25% somewhere else. A shallow soil may be from 5-10 inches one place and 20-30 inches somewhere else. Efforts are being made to standardize meanings.

PART IV

SOIL SURVEY INTERPRETATIONS

General Interpretations

Interpretations have become an important part of each soil survey. Greater use is being made of soil survey maps than ever before. The process of making interpretations commences with the soil survey itself.

The purpose of interpretations is to provide users of soil maps with predictions about the behavior of each kind of soil under defined situations. They are not recommendations for specific tracts. Interpretations provide information for broad areas or for one or more kinds of soil. Interpretations and decisions made from their use depend partly on economic considerations.

Interpretive Soil Groupings

Soil grouping is simply a device for generalizing and presenting interpretations. Soils of an area can be grouped into any number of classes depending on the detail needed. These groupings are a simple form for presenting interpretations that easily show how the soils compare with one another. Both specific and general interpretations are needed depending on the needs of the many users. Real estate, appraisers, ranchers, tax assessors, and technical conservation people all have different needs for information. Ideally interpretations should have the greatest simplicity for each purpose without loss of any necessary exactness. Of course its use should then be strictly limited to its purpose or mistakes of serious consequence may result.

To obtain full information about a particular soil one must go back to the individual soil description and the data about it. When soils are grouped for simplicity or generalization some precision is lost. For example, soils can be grouped according to their erodibility under grazing, any soil in this group is essentially the same in this one quality but may be unlike in other qualities.

In making interpretations it is not possible to predict the behavior of individual soil characteristics since one influences the others. Each soil is a unique combination of characteristics with many potentials for interactions resulting in a unique and predictable behavior. Individual characteristics need to be studied however, to help us understand the whole soil. Soil characteristics can be seen and measured in the field or in the laboratory. Qualities differ from characteristics. Qualities result from interactions between soil characteristics and practices. Soil fertility, productivity, tilth and erodibility are examples of qualities.

Relation of Interpretations to Soil Classification

In soil classification one deals with a large number of soil characteristics. Logical combinations are developed as classificational units. They are called series, types and phases. Soil is a three dimensional body, it has area, shape, and depth. From its characteristics it is possible to discover its history and predict its future behavior.

A soil individual cannot be defined by an individual soil profile since a profile occupies little more than a geometric point. A soil has area with a range in profiles limited by our definitions.

Basic Soil Classification and Soil Interpretation

Soil classification is not permanent, yet it is much more permanent than the interpretations made from it. As new chemicals, machines, and plant varieties and other new methods of soil use become available changes are needed in our interpretations. Economic conditions also change, making it necessary to present new alternatives of use. Soil survey interpretation is a continuous process.

Care should be taken to see that interpretations are not worked into the soil classicication. Soil classification must be based only on recorded soil characteristics. Otherwise the maps will go out of date rapidly and cannot be reinterpreted and used under new situations.

Soil Profile Descriptions

Detailed descriptions are made by the soil scientist as he does his mapping. He adds new or improved information to the mapping legend and writes descriptions of new soils he finds. Many descriptions are written during the course of the survey. Ordinarily two or three descriptions are required for the less extensive soils and six or more for extensive soils and those having a wide range in important profile characteristics. From this information the range in characteristics can be determined and a modal concept defined.

Soils are carefully described in standard terms so other soil scientists know exactly what the soil looks like and how it is related to other soils. An example of such a profile would be as follows:

Profile as described: 600 feet west of W¼ corner, Sec. 3, T. 4 S., R. 51 E., M.P.M.

File No: SCS 232C 17JLP62

Soil Profile: Bainville silt loam

A_{11} 0 - 2" Light gray (2.5Y 7/2) silt loam, light olive brown (2.5Y 5/4) moist; weak fine granular structure; soft dry, friable moist, nonsticky and nonplastic; strongly calcareous, pH 8.4. Gradual boundary.

A_{12} 2 - 7" Light brownish gray (2.5Y 6/2) silt loam, olive brown (2.5Y 4/4) moist; weak fine granular structure; soft dry, friable moist, nonsticky, and nonplastic; strongly calcareous; pH 8.4. Gradual boundary.

C 7 - 15" Light brownish gray (2.5Y 7/2, 6/2 and 8/2) silt loam, light yellowish brown (2.5Y 5.6/4 and 6/2) moist; massive structure; soft dry, friable moist, nonsticky and nonplastic; strongly calcareous, pH 8.4. Abrupt boundary.

R 15+" Light gray (2.5Y 7/2, 5/4 and 6/2) dry; very fine sandy shale; massive with fractures a few inches apart; friable moist, nonsticky and nonplastic; mildly calcareous, pH 8.2.

<u>Terms Used in Profile Descriptions and their Significance</u>

<u>Location</u> - Distance and direction from a legal corner or subdivision giving the section, range and township. It may be necessary to recheck some feature of the profile.

<u>File No.</u> - Many soil profile descriptions are made during the course of the survey and a systematic numbering system is needed.

<u>Soil Profile</u> - The name and texture of the soil series or taxonomic unit. The series name is only tentative and subject to change until after the final correlation has been made and before publication of the soils report.

Horizons - There are almost numberless ways in which the soil profile may vary. It is not absolutely necessary to name the various horizons but in so doing the usefulness of the profile description is increased. Simple numbers like 1, 2, 3, 4, etc. may be used to describe horizons; but the letter designations of A, B, C, and D are more useful because they show genetic relationships. They indicate the dominant kinds of departures from the parent material. An arabic number following the letter symbol subdivides the horizon further. Each arabic number has a different implication when combined with a different letter symbol. Lower case letters as b, ca, cs, are used as suffixes to indicate subordinate departures from the assumed parent material. Or they may be used to indicate specific kinds of departures from the definition assigned to the symbols A, B, C, and D. These suffixes follow the arabic number in the symbol, for example B3ca.

Some of the horizon designations have been modified in the new classification system (7th approximation). A complete list, with definitions, appears in the Appendix for both the new system and the older system used in the Soil Survey Manual (U.S.D.A. Handbook No. 18).

Depth - In the temperate regions soils are usually examined to depths of 3 to 5 feet. Shallow soils and Lithosols (soil having little development over bed rock) are not examined so deeply.

Depth of each horizon is measured from the top of the A_1. The thickness, while not given separately is the difference between the horizon limits. For example, a horizon described as 7-15" is 8 inches thick starting

7 inches below the ground surface extending to a depth of 15 inches. A range in depth may be given if a horizon has tongues extending down into the next horizon or horizons.

Soil depth, by itself, may give some indication as to soil capability. Shallow soils, regardless of how good other soil characteristics may be, lack water holding capacity and capacity for root growth deeper soils have. From the standpoint of productive capacity and response to management this deficiency is quite important. The recovery of shallow range sites from disturbances, such as over-grazing, erosion, drought, etc., is much slower than on the deeper more permeable soils.

Color - Color names and mathematical notations are taken from the standard Munsell color charts. When the soil is streaked or mottled with contrasting colors, principal colors are noted separately. For example, in the C horizon of the Bainville silt loam profile, shown above, the color is given as (2.5Y 7/2, 6/2 and 8/2). The 6/2 and 8/2 are mottled colors. Colors may be given for dry or moist soils or both. A more detailed description of hue, value and chroma, the three variables, that combine to describe all colors, may be found in the Appendix.

Soil color is an indicator of certain other important soil characteristics. A dark color may mean a high quantity of organic matter or as is more usual in semi-arid regions, the presence of certain minerals found in the parent material. A light soil color may mean the presence of flour lime. Imperfectly drained soils are often mottled with gray, yellow and brown colors. Mottling also occurs in soils not completely weathered and in those having lime accumulations.

Structure - The aggregation of primary soil particles into compound particles separated by surfaces of weakness. There are four primary types or forms of structure (1) platy, (2) primslike, (3) blocklike and (4) spheriodal or polyhedral. The descriptions of soil structure note (1) the shape and arrangement, (2) the size, and (3) the distinctness and durability of the visible aggregates. For example, a weak fine granular structure is one with poorly formed indistinct soil aggregates, barely observable in place, having a size of 1 to 2 millimeters in diameter and with spheroidal or granular form.

Approximately one hundred different simple structures are possible by the combination of the three elements of structure, (1) grade, (2) size and (3) form. Many soils however have compound structure so actually the different kinds of structure are quite numerous. Large aggregates may break into smaller aggregates. For example, weak fine prismatic breaking to strong fine and medium blocky structure.

Some soils are said to be structureless in that there is no observable aggregation or orderly arrangement of natural lines of weakness. If it is coherent or sticks together it is massive, as found in many undeveloped soils, hardpans and claypans. Noncoherent soils are the coarse textured soils, sands and loamy sands.

The influence of structure on soil productivity, permeability and root growth is an important factor. Water and air intake of soil is strongly affected by structure, which in turn has an influence on erosion.

Subsoil structure will influence water holding capacity, fertility and drainage.

Cultivation tends to break down structure by breaking up soil aggregates, destroying organic matter and compacting the soil. Growing plants has a beneficial affect on structure by returning organic residue to the soil. The soil structure can also be changed by too much water, and water high in soluble salts and adsorbed sodium.

Erodibility of soil by wind is influenced primarily by soil structure and stability of structure in a dry condition. Specifically the erodibility is influenced by the proportion, size and bulk density of the erodible soil particles. Generally particles having a diameter smaller than 1 millimeter are erodible by wind. A soil resistant to movement by wind should have at least two-thirds by weight nonerodible fractions.

Texture - The relative proportions of sand, silt and clay determine texture. A chart showing the relative percentage of the three soil separates in each textural class may be found in the Appendix. It is observed in the field by moistening a small sample and rubbing between the thumb and forefinger. Definitions of the feel of the basic soil textural classes are listed in the Appendix. These definitions are suggestive only. None can be made for all groups of soils or for all persons. Each must work out for himself the ability to determine soil class by feel. With experience a high degree of accuracy can be achieved; however a mechanical analysis in the laboratory will be needed for complete accuracy. The texture of most soils change from one horizon to another. Commonly the B horizon (a horizon of illuviation) contains more clay than the horizon above it.

Soil texture usually relates directly to the parent material. Parent materials high in clay break down into soils high in clay. Surface soil texture may be changed by wind and water erosion or by water applied to the soil high in silt, clay or colloidal material.

No one soil texture can be said best for plant growth. Heavy soils, those high in clay, are capable of holding large amounts of water; but much of it is held too tightly and is unavailable to the plant. Sandy soils however allow too much of the water to drain away and under a humid climate they may be droughty.

Under arid or semi-arid conditions the sandy soils may be the least droughty. Most of the water that falls will infiltrate rapidly and then is readily available to plants. The medium textured soils, loam and silt loam are on the average the most efficient in releasing moisture to plants.

Soil Consistence - The combination of properties of the soil material that determine its resistance to crushing and its ability to be molded or changed in shape. Consistence has important implications on the engineering properties of the soil. In the profile description consistence is described by such words as soft, friable, plastic, nonplastic, sticky, nonsticky and others.

Calcareousness - Refers to the calcium carbonate found in certain soils, particularly in arid and semi-arid regions. Soils made alkaline by calcium carbonate alone usually have pH values of under 8.5.

Carcareousness may seriously influence plant growth.

When these soils are tested for calcareousness with diluted hydrochloric acid they fizz or effervesce. Terms used to describe calcareous soils are, weakly, mildly, slightly, moderately, highly, strongly, etc..

pH - A numerical designation of relatively weak alkalinity and acidity as in soils and other biological systems. A pH with a value of 7.0 indicates neutrality, lower values indicate increasing acidity, higher values increasing alkalinity. The importance and effect of pH on soils is given in detail in the section on "Salts and Alkali".

Horizon Boundaries - Horizon boundaries vary in distinctness, and in surface topography. Some boundaries between highly contrasting horizons are sharp and clear, other boundaries are diffuse and indistinct. Horizon topography varies also and may be described as smooth, if nearly a plane, wavy or undulating, irregular if irregular pockets are deeper than their width and broken if parts of the horizon are unconnected with other parts. More detailed and technical information on terminology for describing horizon boundaries may be found in the Appendix.

Salts and Alkali

1. Nature of saline and alkali soils - There are different kinds of salt found in the soil. Salts occurring in saline soils are the normally neutral, or nearly neutral, salts like the chlorides and sulfates of sodium, calcium, and magnesium. These salts are not strongly alkaline, ordinarily the pH is between 7.0 and 8.5. Saline soils are often recognized

by the presence of a white salt crust on the soil surface, and by a damp, oily-looking soil surface devoid of vegetation, except for halophytes. Streaks and spots of visible salt are often found in the soil profile. Often called white alkali soils.

An alkali (or sodium) soil contains excessive amounts of adsorbed sodium, 15 percent or higher. These soils may be highly alkaline, usually with a pH of 8.5 or higher, but do not contain excessive amounts of soluble salts. Alkali soils are often recognized by the presence of slick spots highly impermeable to water. These soils are often called black alkali.

A saline-alkali soil contains excessive amounts of soluble salts and adsorbed (exchangeable) sodium. Seldom is the soil highly alkaline (pH above 8.5) in reaction. The appearance and properties of these soils are similar to the saline soils. However, if the excess soluble salts are leached out the soil will become strongly alkali.

2. Origin of saline and alkali soils - Salts in the soil come primarily from decomposition or weathering of sedimentary rocks and primary minerals. Soils affected by salts occur mostly in arid or semi-arid regions. Under a humid climate soluble salts are leached out and washed into the oceans. In arid regions these soluble salts are not completely leached and are transported only locally because of less rainfall and higher evaporation. Saline soils usually occur along drainageways or where salts are deposited by water and in areas where there is a high watertable.

Alkali soils are formed when water containing a high proportion of sodium comes in contact with the soil, the sodium cation becomes the dominant one in the soil solution and replaces part of the adsorbed calcium and magnesium.

3. <u>Management of saline and alkali soils</u> - Salt affected soils require special management practices. Irrigation water quality and soil texture determine to a large extent the kind of management needed. Water having a salt content of over 5 millimhos electrical conductivity per centimeter (3000 parts per million or about, 4 tons of soluble salt per acre foot of water), can seldom be used. It depends on the amount of soluble salts and exchangeable sodium already in the soil. Water having excess amounts of sodium is not satisfactory for irrigation.

The fine textured, deep, slowly permeable soils cause the most problems in salinity control. Medium and fine textured soils having good structure underlain by a sandy aquifer ordinarily cause few problems. The coarse to moderately coarse textured soils, usually quite permeable, offer the least number of problems in the control of salinity and alkali.

Saline soils are improved by drainage if there is a high water table and by frequent leaching of excess soluble salts by irrigation.

Removal of excess soluble salts (if present) in an alkali soil is not enough to restore it to productivity. The adsorbed sodium must be replaced by using soil amendments containing calcium, magnesium or sulfur. Soil amendments vary in cost but generally the faster acting ones are most expensive. Limestone, one of the cheaper amendments is only occasionally useful, most alkali soils already contain lime. Soil structure should be improved by the addition of organic matter.

Management of a saline-alkali soil is similar to an alkali soil. Soluble salts must be leached out and the exchangeable sodium removed by the addition of amendments. Alkali soils should be leached immediately following the application of the amendment, except when sulfur is used. Leaching removes the soluble salts and at the same time dissolves the amendment and carries it downward into the soil. When sulfur amendments are applied they should be applied 2 or 3 months before leaching to allow time for it to oxidize and form gypsum.

4. Effect of saline and alkali soils on plants - Salts affect plant growth in two ways: (1) by reducing the amount of water the plants can take from the soil, because of the increase in osmotic pressure , and (2) by causing toxic effects on the plant. When the plant roots take up water, the salts are left behind and the soil becomes saltier. Indirectly plants will be affected by changes in soil structure due to salts and sodium.

Soil Characteristics

Individual soil characteristics such as texture, structure, etc. can not be used to predict the behavior of the whole soil. All characteristics are interrelated and influence each other. Each soil is a unique combination of many characteristics with many potentials for interaction. To fully understand the whole soil the individual characteristics need to be studied and their significance realized.

Specific Interpretations

Range Site Classification

A range site is a distinctive kind of rangeland with a certain potential for producing range plants. The inherent productivity of a range site, like that of other agricultural land, depends upon the climate and soil distinctive to it. The ultimate expression of its particular combination of environmental conditions is the characteristic plant community that occurs on it. Furthermore, the range site retains its ability to reproduce this climax plant community so long as the environment remains unchanged.

A range site is the product of all its environmental factors. Its distinctive climax community is relatively uniform throughout the site. Thus a range site is not only an entity of the environment but is also a specific area of land whose characteristic features can be recognized and described. Any natural plant community will have variation in its relative composition because of variation in the microenvironment within a range site. Consequently, the native plant community representing the climax for the site is composed of a characteristic grouping of species not necessarily in precisely defined proportions.

Several methods are used to determine the potential climax plant community. The most important are:

1. Study of relic or relatively undisturbed areas of the same or similar soils.
2. The comparison and evaluation of areas having similar soils, topography and climate where grazing records are available.
3. Critical appraisal of data from ecological and soil research.
4. Comparisons of similar areas receiving various degrees of grazing use and on areas excluded from this use.

5. Study of ranges that we consider properly used and still in near climax condition.

6. Historical accounts, early photographs, and ecological and botanical literature are all valuable for determining the nature of the climax plant cover.

Evidence from any single source is not likely to be conclusive. Care must be taken in evaluating the facts to be certain they are not the result of some abnormal condition such as fire, drought, grazing, rodent disturbance, excessive soil erosion or soil deposition or accumulation of snow or water. Some disturbance by these conditions is normal on all range sites. The effect of these disturbances was aptly described by Dyksterhuis as follows: "The physical environment, with all of its climatic and edaphic factors and their innumerable interactions and gradients, supports many measurably different plant communities in apparent stability with local site conditions. When grazing by domestic livestock is superimposed by thousands of pastures grazed in various ways, the climax pattern tends to be obscured, and there is an overall increase in the number of plant communities."

Disturbances as described will not permanently change the range site unless they are particularly severe. These disturbances can usually be corrected by good management and time. However, if these disturbances are so severe and prolonged that they cause severe erosion, reduce soil fertility, change the water level or otherwise change the soil conditions to the extent that revegetation is seriously effected, the productive capacity of the site is changed. When the productive capacity is so altered a different range site should then be recognized.

Range sites are recognized as being different when:

1. There are differences in the kinds or the proportion of plants making up the potential plant community.
2. When there are significant differences in the total herbage yields even though the potential plant community is similar.

These differences must be great enough to require some change in management, such as rate or season of stocking. A difference in the soil or in the climate does not necessarily mean a difference in range site, unless these factors result in a significant difference in the potential plant community. The effect of any individual factor of the environment varies; consequently, the total environment must be considered in determining the range site.

Range sites are given names to aid the technicians and ranchers in identifying and remembering the significant kind of range land in a locality. Range site names are brief and should be based on readily recognized permanent physical features, such as, kind of soil, climate, topography, or combinations of these features. Generally range site names describe the kind of land e.g., silty, sandy, clayey, thin breaks, badlands and so forth. Plant names should not be used such as pinon, juniper, sagebrush hills, etc. since vegetation may change or disappear with changes in range condition.

In areas where a standard soil survey has been completed range sites can be determined from the soil map. Boundaries of soil mapping units and of range sites are frequently the same on rangeland. The range site description for Montana may be found in the Appendix.

Engineering Interpretations

Properties of the soil that affect their use for engineering purposes are often summarized into tables in the soil survey report. These properties can be used for making general interpretations for engineering planning. Detailed inplace conditions of the soil should be studied at the proposed construction site.

Some terms, and brief meanings, used in making interpretations are listed below. A few of the terms are used primarily by soil scientists and may be unfamiliar or little used by engineers.

PERMEABILITY - Related to the movement of water (percolation) through the undisturbed soil material. Permeability is expressed in terms of a quantity of water per unit of time. In the absence of precise measurements, study of the structure, texture, porosity, cracking and other characteristics of the profile, in relation to local use, the soils may be placed in relative permeability groups. Soil permeability is customarily described as being impervious, those having less than 1 foot a year permeability, semipervious, 1 to 100 feet per year and soils having a permeability of over 100 feet per year as pervious.

SALINITY - The amount and kind of soluble salts found in the soil may be an important factor when the suitability of a soil is being considered for construction of embankments. Soluble salts are more objectionable in materials having high permeability than those with low permeability. Salinity is expressed in millimhos per centimeter of the saturated soil extract at 25° C. and in parts per million (p.p.m.). Parts per million are considered to be equivalent to milligrams per liter.

SALINITY

	Millimhos	P.P.M.
None	Less than 2	0-1200
Slight	2-4	1200-2400
Moderate	4-8	2400-4800
Severe	8-16	4800-9600
Very severe	16-over	9600-

Where salinity of the soil is not of significance it is usually omitted from the report.

DISPERSION - The degree and speed which the soil structure breaks down or slakes in water. There are two meanings with respect to the method of determining the value:

1. Breaking up of soil aggregations in the field due to rain.

2. Breaking up of soil aggregations in a laboratory sedimentation tests.

In most soil survey reports, the terms high, moderate, and low are used to describe dispersion. An easily dispersed soil seals over and resists penetration of water and air and is readily eroded by wind and water.

SHRINK - SWELL POTENTIAL - As moisture leaves the soil, the soil shrinks and decreases in volume in direct proportion to the loss in moisture until a state of equilibrium is reached. The shrinkage will then stop even though additional moisture can be removed. This point where the shrinkage stops is called the shrinkage limit. It is expressed as the moisture content, by over-dried weight of the soil, needed to fill the soil voids. In soil survey reports, it is expressed in terms of low, moderate, high or very high. The shrinkage limit of a soil is a general index of clay content. Swelling or expansion of the soil may take place with the addition of water. The amount is generally in relation to the amount of clay materials in the soil. Many clays, however, do not expand a great deal when saturated. The montmorillonite clays have a very high shrink - swell potential.

<u>SOIL COMPACTION</u> - Compaction means to artifically densify or increase the unit weight of a soil mass by rolling, tamping, vibrating or other means. Soil density is usually expressed as pounds of wet or dry soil per cubic foot and is measured in terms of its volume - weight. These volume - weights are designated as wet density and dry density respectively.

<u>COMPACTION CHARACTERISTICS</u> - Compaction varies due to the influence of several factors. Of primary importance are: (1) moisture content of the soil, (2) soil characteristics, (3) the type and amount of compactive effort and (4) the thickness of the lift to be compacted. Granular soils with few fines generally have good compaction characteristics for pervious embankments. The well graded materials classified GW and SW in the Unified Classification System show better results than poorly graded soils GP and SP. Soils in groups GM and SM, coarse grained soils with fines of low plasticity, show good compaction characteristics. The range in the moisture content for good compaction nay be very narrow, and close control is needed. This is also generally true for the silty soils in the ML group. Gravels

and sands with plastic fines, groups GC and SC, have excellent to good compaction characteristics, varying somewhat with the character and amount of fines.

The compaction characteristics of fine grained materials are variable, lean clays CL being the best, fat clays, CH and lean organic clays and silts, OL, being fair to poor. The inorganic silts and organic silts, MH and OH, usually have poor compaction characteristics.

These values are for general guidance only. For design or construction control the results of laboratory tests should be used.

SUITABILITY FOR EMBANKMENTS - Permeability, strength, and compaction characteristics are the three major properties of the soil that influence their suitability as embankment material.

Gravelly and sandy soils having few or no fines, GW, GP, SW and SP are stable, pervious and are well suited to road construction but not for earth dam embankments. The groups, GM, GC, SM and SC, gravels and sands with fines have variable embankment qualities depending upon the nature of the fines and the gradation of the entire sample; but are generally well suited for earth dam embankments.

The CL group are fairly well adapted for the construction of impervious embankments and well suited as core backfill material. Soils of the ML group may or may not have fair compaction characteristics and need close control in the field. The MH soils are not suitable for earth dam embankments. Soils in the CH group may be used in embankments having flat slopes but they have detrimental shrinkage characteristics which may cause cracking.

LIQUID LIMIT (LL) - The liquid limit is the moisture content expressed as a percent of the dry weight of the soil at which a soil passes from a plastic state to just before the soil mass becomes fluid under the influence of a series of standard shocks.

Sandy soils have low liquid limits of around 20. The silts and clays may have a LL as high as 80 to 100 but most clays in the United States will run 40 to 80. The montmorillonite clays may have considerably higher limits.

PLASTIC LIMIT (PL) - The moisture content expressed as a percent of the dry weight of the soil at which a soil changes from a plastic to a brittle state. Clay content governs the plastic limit. Some silty and sandy soils are termed nonplastic, they have no plastic limit.

PLASTICITY INDEX (PI) - The numerical difference between the liquid limit and the plastic limit. It is the range in moisture content at which a soil is in a plastic condition. A small plasticity index, such as 6 means that a small change in moisture content will change the soil from a semisolid to a liquid condition. A large PI of 20 would mean that considerable moisture could be added before the soil became fluid.

If the plastic limit of a soil is equal to or higher than the liquid limit or either one cannot be determined, the soil is nonplastic (NP) and the PI equals 0.

The liquid limit, plastic limit and plasticity index, along with the shrinkage limit are often called the Atterberg limits after the originator of the tests.

PART V

SUMMARY AND CONCLUSIONS

Advantages of Soil Survey

1. As management of public land becomes more intense, greater knowledge of our basic resource, the soil, will be needed. A sound conservation program on rangeland starts with a knowledge of the soil, just as it does on crop land.

2. Soils information will not be rapidly outdated for future use. Our predictions or interpretations of soils information may need to be revised occasionally because of technological and economic changes; but the actual soil classification is relatively permanent under ordinary circumstances.

3. Soil is one of the more stable factors of the plant environment. Management decisions based upon the soil and its capability will be less changing and have a sounder basis than if based primarily on the present vegetation.

4. Practical application can be made of soils information in land use planning, land classification and other purposes (see the section of the report on BLM uses of soils information).

5. As experience is gained in using soils information, new uses and interpretations will be found. By describing, classifying, and mapping the soils, experience is acquired which will help in making interpretations needed for management. Confidence in the results obtained from using soils information will be gained and encourage

wider soil survey information use.

6. With the aid of soils maps the experience and knowledge of many technicians can be correlated to the soil. Practices which these men have found to be successful or unsuccessful, because of the soil, can be noted and the information used in future planning and design. A place on Form 4-1209 (Project Completion Report) can be provided to record the soil type. Over a period of years through project inspection it may be found that certain conservation practices are more successful on a particular soil or soils than on others.

   It is realized however that factors other than the soil will influence success of conservation practices. It may not be possible to accurately determine the specific cause. Care should be exercised in making interpretations or wrong conclusions may be reached.

7. Low intensity soil survey, the kind usually made on rangeland, can be done rapidly at a reasonable cost (about 6 to 8 cents per acre) on large blocks of land.

Disadvantages of Soil Survey

1. Soil surveys, compared to range surveys, are slow and costly. If all of the Bureau administered land in the Miles City District were in one block, with no private land, it would take at least 16 man years to complete, and cost about $180,000. However, much of the Bureau land is interspersed with private land. It

would also need to be mapped to complete the unit or allotment management plan. Therefore, 30 to 40 man years and $350,000 may be required for the district soil survey.

2. Soils and range site information, as pointed out in the Nevada pilot soil survey study, will be of little value in the adjudication process, because of; (1) the 1967 adjudication deadline, (2) range site data is no more reliable than our present method of resource inventory and, (3) it is more expensive and time consuming than our present method of range survey.

3. The information obtained from soil surveys is general in nature and its use will be mainly for planning. Soils are so variable that on-site soil tests must be made to accurately determine soil properties. Many of the mapping units contain inclusions of other soils, often highly contrasting ones. It is not possible to predict accurately the kind of soil inclusions or percent composition each makes of the total. Usually a list of the major soils known to occur is given for each mapping unit and their range in composition. The location or topographic position in the landscape of the different soils in a mapping unit is not always predictable. A typical example of soil composition found in a complex mapping unit is:

Bainville	50-90 percent
Midway	5-20 "
Pigeye & Campspass	0-30 "
Shale & sandstone outcrop	1-5 "
Chestnut & Brown soils	0-20 "

The modal composition is, Bainville 80 percent, Midway 10 percent, Farland (a Chestnut soil) 5 percent, Pigeye 4 percent and shale and sandstone outcrop 1 percent.

Bureau of Land Management Uses of Soils Information

The activities listed below in which the Bureau can use soil survey interpretation are quite general. Soils information, like any new tool will have many uses unrealized until the Bureau actually starts making and using soil surveys.

Activities of the Bureau in which soil interpretations can be used are:

1. Allotment Analysis and Management Plans - Soils information can be used in determining the capability or potential of a range allotment. Soil, a common denominator, will help pull together the grazing management, the range studies and the range development and improvement programs into a workable management plan.

2. Land-Use Planning - Soil survey information is the foundation for classifying land according to its productive potential and capability, or the degree to which the land can safely be used. Preliminary watershed planning can be facilitated by the use of soil maps and interpretations. In writing conservation plans, both general and specific soils information will enhance the usefulness of the report.

   a. Soil Stabilization Practices Planning - With the aid of soil survey maps, range survey maps, water resource maps and other maps, soil stabilization practices including seeding, contour furrowing, deep plowing, brush control and weed control can be planned in considerable detail.

Practices designed to stabilize the soil must first be considered on the basis of soil. This means an examination in depth, not merely a look at the soil surface.

Soil maps and soils information will be an aid in explaining to local ranchers, and others, why certain practices are better suited to one location than others. Soils information available for presentation during field trips and tours will give both technical and nontechnical persons a clearer understanding of the problems and limitations involved.

b. Water Management Planning - Preliminary planning for detention and diversion dams, waterspreaders, and dikes can be made by using information found in the soils report. Areas of soils known to be completely unsuitable for certain practices can be avoided when planning. For example, pan spot soils, alkali soils, low fertility soils, dense clay soils, extremely permeable soils and areas having too much slope can be avoided when planning waterspreaders. Areas having sandy soils can be avoided in planning stockwater reservoirs. When planning waterspreaders and dikes considerable thought should be given to the affect additional water will have on the soil.

With enough soils information it may be possible to correlate the performance of many of the water control structures with the soil mapping units. This type of information can be used in future planning and the design and maintenance of structures. Estimates of water yield and amount of sedimentation can be based partially on soils information.

3. Land Classification - Interpretive soils information, such as capability groups, range sites and crop yield estimates (based on information gathered from local farmers) can be used in land classification. This information will not only be of value in classifying sites proper for intensive development but also for rangeland.

   Generalized soils maps showing the nature of the soils, their productivity and susceptibility to erosion can be used in master unit planning.

4. Forest Rehabilitation and Stand Improvement - The use of soils information in their field is relatively new, compared to agricultural uses. The U.S. Forest Service has been actively engaged in soil surveys for the last 6 or 7 years, and it is expected rapid progress will be made in forestry applications of soils data.

   Some of the expected forestry uses of soils information are:

   a. Growth rates of different tree species may be predicted on the basis of soil properties.

   b. Predictions of tree suitability to, and rate of growth on bare land to help set values on land intended for reforestation.

c. The eventual site quality of deteriorated land may be predicted on the basis of soil-tree relationships.

d. Soil-tree relationships also assist in choosing the best tree species to seed on degraded sites and in the management of stands to maintain the more desirable species.

e. Results of research are usually presented on the basis of a particular soil type.

f. Determine which soils would be subject to severe erosion if the timber were harvested.

5. <u>Survey and Design of Access Roads</u> - The soil survey will be an aid in preliminary selection of road locations. If there is more than one possible route, soil may be one of the determining factors on which route is selected. Areas of unstable soils, highly erodible soils, and gumbo or heavy clay soils, can be avoided. After the road location has been marked in the field it can be plotted on the soils map to determine the major soil types crossed. From this information, the number and locations of soil samples needed for laboratory analysis can be determined.

The location of probable sources of sand and gravel are usually shown on soils maps.

6. <u>Selecting Sites for Exclosures and Other Range Studies</u> - Soils information will help the range manager determine which areas

are different even though the present plant cover is similar. Each soil may have a different response to management. If soil differences are carefully considered, the information and experience regarding land use can be more accurately extended from exclosures, study plots, transects, pastures and other small areas to the larger areas to which they apply.

Exclosures and other studies should be located in a typical area of an extensive complex or other mapping unit. It is important to know which soils are represented by each exclosure or study. Unless the soil is understood the observer may draw wrong conclusions. For example, an exclosure in an area having generally shallow soils, supporting one general range type, may be on a nontypical area of deeper soils. It might appear from observation that the difference in vegetation inside and out was due to improved management and that the entire broad area could similarly be improved. Whereas the vegetative improvement in the exclosure is typical for only a small area.

Soil Survey Cost

Low Intensity Mapping

Compared to a range survey a low intensity soil survey is a detailed survey. Consequently it will be slower and more expensive than the range survey. The possibility of doing a range survey and soil survey concurrently is remote. There are few persons qualified to do both and most range surveys for adjudication will be completed before a soil survey can cover any appreciable area.

Soil survey cost will vary in different parts of the country because of the difference in land pattern, topography, length of field season and mapping intensity. Most Bureau administered land is grazing or forest land and would be low intensity mapping. However, where these lands are interspersed with private lands there will probably be some medium intensity mapping on farm lands, and the survey cost will be increased. Rangeland can be mapped much faster than medium and high intensity agricultural lands. The mapping units on rangeland are predominantly soil associations and complexes (groups of soils related geographically in defined proportional patterns) and require few soil examinations.

Powder River Survey Area

The survey area consists of about 90 percent rangeland (low intensity survey) and 10 percent dry and irrigated cropland (medium intensity). The field season is usually from April 15 to November 15 with a yearly variation of plus or minus 15 to 30 days. This amounts to approximately 150 possible working days during the field season. Topography in the area (1,760,000 acres, not including the National Forest) is gently rolling to extremely steep. Most of the area is moderately to steeply sloping.

It required nine (9) man years to complete the field mapping. Included in this time are other field activities such as, field checking of mapping, writing profile descriptions, progress field reviews, collecting correlation samples and transecting mapping units. During the winter, field sheets were checked for accuracy, mapping unit acreages figured, soil interpretations made, and changes needed in the descriptive legend rewritten.

Survey party members were in grades of GS-5 to GS-11. The cost for survey party personnel, estimated for the nine man years of field mapping and related activities would be about 4 cents per acre. Vehicle expense, per diem, laboratory analysis of soils, equipment, office supplies and aerial photos would add about 8/10's of a cent per acre to the cost. Soil Conservation Service, state and area personnel costs of conducting progress field reviews, correlation reviews, and secretarial costs during the coarse of the survey and after completion of the mapping would increase the cost per acre by 2 cents. A realistic cost for the Powder River survey would be 7 to 8 cents per acre.

This cost does not include BLM State Office personnel expense or SCS Regional and Washington costs. It does not include the cost of publishing the soil survey report.

The cost of mapping on scattered lands and cropland would be much higher than for rangeland, possibly 20 to 30 cents per acre.

Soil Survey Problems

Personnel

The Bureau of Land Management has few experienced soil scientists willing or capable to start or carry on a soil survey. Soil scientists for the most part would have to be hired from other state and federal agencies. Soil scientists hired, particularily the party leaders, should be extremely competent, versatile and resourceful. These are the men that will form the foundation of the Bureau's soil survey program.

There are few soils majors now being graduated from the colleges and universities. Two of the reasons are, lack of interest in soils by the students and a soils curriculum top heavy in chemistry, mathematics and physics. For those persons going into research or teaching these courses are necessary and desirable. However, we should be realistic in recognizing these courses are not required by most federal agencies hiring soil scientists. Many of the soil scientists hired have only the minimum number of semester hours of soils (ten) and have graduated in fields of agriculture other than soils.

Soils work is not easy. It involves hard physical work, often under adverse weather conditions. At times it is very tedious, tiresome and lonely. It demands the ability to make decisions, not only on practical matters but also on the abstract. Because of these reasons, many soil scientists become discouraged or disenchanged after a few years of field work and transfer into other jobs.

Cooperation

The Bureau will depend a great deal upon the SCS for initial reviews, progress field reviews and soil correlation, close cooperation will be necessary. Generally the SCS in Montana has been quite cooperative in all phases of the soil survey pilot study. No major problems are expected in a soil survey program.

If the BLM becomes actively engaged in soil survey work the SCS may need more supervisory personnel to correlate our work with theirs. Training of personnel in the latest techniques and procedures used in the Standard Soil Survey will have to be done by the SCS.

Publication of Soils Report

One of the principle tasks of the soil survey, as far as the SCS is concerned, is publishing the soil survey report. Will this be the goal of the Bureau? Or, will the BLM as does the Bureau of Indian Affairs (BIA) not assume responsibility for writing the report. In areas being mapped by the BIA, the SCS will often appoint one of their soil scientists to periodically work with the BIA survey team. His responsibility is to maintain the descriptive legend and give guidance to the survey (the BIA does not make Standard Soil Surveys). After completion of the survey the SCS will then write the soils report. The BIA will write a soil and range resource inventory report for their own use.

For areas being surveyed cooperatively by the Forest Service (FS) and the SCS (both agencies of the Department of Agriculture and both making Standard Soil Surveys) reports are published jointly. Reports are published solely by the Forest Service when the area is dominantly forest lands. One major problem which can arise in the publication of combined reports is the matter of soil interpretations. Some of these problems can be worked out before the survey starts in the preparation of the soil survey work plan. Other problems must be settled as they arise. Many problems of interpretation can be resolved when drafting the soil survey report outline. An example of an outline showing contents and arrangement can be found in the Appendix.

Survey Methods

One of the biggest problems of soil survey is, which method of soil survey should be used. Even though evaluating survey methods was not one of the objectives of the pilot study, it is well to have some understanding of the methods now being used. There are two methods or systems of soil classification used by most soil survey agencies. They are: (1) the natural or taxonomic system, the method used by the Forest Service and Soil Conservation Service and (2) the interpretive or uncontrolled soil legend method used by the Bureau of Indian Affairs (except where the descriptive legend is maintained by the SCS) and the Bureau of Reclamation. The systems are differentiated mainly on the basis of soil classification or lack of any classification.

1. The natural or taxonomic system of soil classification is one in which all relevant features of soils are considered as unique interrelated sets of characteristics, including those important to the practical purposes that the soils maps serve. There is no exclusive emphasis placed on any one or group of characteristics.

    Each soil type is unique. It is a combination of surface features, like slope and stoniness and such internal features as texture, color, structure, chemical composition, thickness and other properties of the horizons that make up the soil profile.

    Any one soil type includes the soils that are alike in characteristics that are significant in the landscape. Those features not significant in the landscape, but are to the use of the soil in farming, forestry and grazing are recognized in making subdivisions within the soil series.

Permanent features that influence response to management are given emphasis in defining the classificational units.

2. The interpretive or uncontrolled soil legend type of survey sets up arbitrary classes of selected soil characteristics, such as structure classes, texture classes, along with arbitrary depth, slope, erosion and stoniness classes. These soil features and surface features or combinations of these selected features are mapped in many different combinations. A symbol showing these characteristics appears directly on the soil map in the area representing that soil.

Advantages and Disadvantages

The advantages and disadvantages of the natural or taxonomic system has already been discussed in the section of the report on "Soil Classification". The uncontrolled soil legend method is not discussed under that section because in reality it is a method of evading classification. This method does not solve the classification problem but merely postpones it. The time to make the classification is before and during the survey and not after it is over.

When using the uncontrolled legend, in which classes of certain selected soil features or combinations of selected features are set up independently of one another and used in any combination, there may be hundreds or even thousands of mapping units. For example such a scheme might include:

50 different soil types (based on soil depth, surface texture, permeability, land types, etc.)
20 different inhibitory factors
10 structural and/or textural groups of the subsoil
8 slope classes
7 erosion classes
15 parent material derivatives or positions
3 precipitation zones

The number of different combinations of these factors would be quite high and errors and inconsistencies are inevitable. Many hundreds of these mapping units may apply to only a few acres.

Many soil features are dependent and interrelated with others, they cannot be arbitrarily separated. A difference in slope that may be critically important in one soil type may not be in another. Differences in stoniness critical to otherwise potentially arable soils may have no significance on nonarable soils.

The excessive categorical detail (the separation of all soils on the basis of small differences in one or more features which may be significant in only a few soils) is probably the greatest source of error in the uncontrolled legend. It greatly increases the problem of accurate soil correlation and in some cases makes it impossible.

The use of symbols (a combination of letters and figures used to identify areas) is not entirely objectionable if they can be tied to a specific or named unit in the natural system of classification. When the descriptive legend is maintained by the SCS, the BIA will assign an interpretive symbol to each mapping unit established by the SCS. The two systems will then correlate. Soil scientists working under this kind of arrangement must keep both the SCS mapping unit name and the BIA code symbol in mind when field mapping.

For example, an area called Bainville silt loam, 15-35 slopes might appear on an SCS published soil map as Ba or BaE or something similar. If possible the first and second letter of the series is used and sometimes a letter showing the slope group. The symbols will vary, depending on other series names and mapping units in the survey area. Each soils report may have different symbols for the same soil. In the soils report, symbols are keyed to the soil name in a legend appearing immediately before the soil maps. A detailed explanation of the soil properties and management problems of each mapping unit including soils interpretations can be found in the text of the report.

The method of assigning symbols to mapping units by the BIA according to selected physical properties may give Bainville silt loam, 15-35% slopes the symbol, $\frac{\text{37h4p19}}{\text{F-2}}$. This symbol will appear on the soil map. By looking in the legend we find what this symbol means.

37 - Very shallow, medium textured soil (a very fine sandy loam, loam, silt loam, or a silt) with moderate permeability (.63"-2.0" per hour)
h4 - Usable substratum 5-10"
p - Lithosol
19 - parent material silty, loamy and sandy shale beds
F - 15-35 percent slope
2 - moderate erosion

With a great deal of experience and use, these complex symbols can be understood without looking in the legend each time. If the proper soil characteristics and features are selected when the coding system is established, limited interpretations for certain practices and purposes can be made directly from the symbol. For other purposes however these coded characteristics may not be sufficient to make accurate interpretations.

In the overall analysis the system used by the BIA does not seem to have any special advantage over the Standard Soil Survey.

Soil Survey Progress in Montana

Reconnaissance Surveys

Reconnaissance surveys were made over a large part of northern and central Montana. They were necessarily very general because of the large area covered and the low mapping intensity.

On a reconnaissance survey delineations were based mostly upon cursory examinations of the soils. Some areas were delineated solely from surface appearance or by interpretations of aerial photographs. Mapping units on reconnaissance soil surveys are usually much broader in their range of allowable variations than the low intensity Standard Soil Survey made today.

Soils information found in the survey reports is generally out-dated. The concepts of most of the soil series have changed since these surveys were made in the 1940's and early 1950's. Reconnaissance surveys were a cooperative effort by the Montana State College, Montana Agricultural Experiment Station and the Bureau of Plant Industry (after 1952 the Soil Conservation Service).

Although these reports are out-dated they can still be helpful in general orientation of soils found in the area. The report also contains useful information on physiographic features, climate, vegetation, history and agriculture. Maps accompanying the report (very small scale) include maps on areas under cultivation, land classification, soil areas, and topography. It may be difficult to find these reports locally. County agents and SCS field offices usually have copies of the local soil survey reports if they have been published.

Detailed Soil Surveys

These surveys are located primarily along the major river valley bottoms on land used for farming. Very little grazing land is included in the area covered by these surveys. Except for the rough broken lands on the valley sides the soils are dominantly of recent alluvial origin.

When the surveys were made, late 1930's and early 1940's, they were considered to be detailed surveys. Under present conditions they lack the necessary detail needed for intensive management of these lands. The maps are published at a scale of 1/2 to 1 inch to the mile. Usefulness of the survey for our work is limited.

Areas included in these surveys are:

Upper Yellowstone Valley Area
Middle Yellowstone Valley Area
Lower Yellowstone Valley Area
Milk River Valley Area
Big Horn Valley Area
Gallatin Valley Area
Upper Musselshell Area
Lower Flathead Valley Area

Standard Soil Surveys

This is the method of soil survey being used by the Soil Conservation Service and the Forest Service. The surveys are much more detailed in field examination, soil classification, and boundary delineation than the older soil surveys. They are also published at a larger scale, usually 3.168" per mile. Mapping intensity and the scale at which the maps are published will depend on the purpose of the survey.

Under intensive agriculture or where the crops are highly specialized, high intensity surveys are often made on aerial photos having a scale of 8 inches equals one (1) mile. The mapping units are dominantly narrowly defined phases of soil types. The soils are examined in considerable detail at close intervals to detect differences significant to use and management.

Soil surveys on arable lands in humid and dryland regions are a medium intensity type survey. Mapping units are predominantly phases of soil types. They are somewhat more broadly defined than the high intensity surveys. Significant differences between mapping units must be detectable and accurately mapped by examining the soil at only moderate intervals.

In areas having a high percentage of range or forest land the soil survey is much less intense than those made on lands under cultivation. These surveys are detailed in the sense of boundary delineation and field examination of each area delineated. Mapping units are broad in their range of soil composition and consist commonly of rather broadly defined phases or combinations of soil types. These mapping units are usually soil complexes or soil associations and are examined at moderate to wide intervals. They sometimes could be mapped separately at the scale being used (SCS in Montana usually map on photos of 4" to the mile); but do not warrant it for the purpose to which the land will be used.

In Montana there are only three published Standard Soil Surveys. Very little Bureau administered land is included in the areas.

Area	Acres Administered by BLM
Wibaux County	24,213
Upper Flathead Valley Area	4,761
Bitterrot Valley Area	360

The following areas will be surveyed or published by 1966.

Area		Acres Administered by BLM
Chinook Area		463,184 *
Powder River Area		251,073
Yellowstone County		87,838
Philipsburg-Drummond Area		43,689
Judith Basin Area		14,985
Treasure County		11,378
Blackfeet Reservation - Cut Bank Area		1,027 *
	Total	873,174

These areas are either being surveyed solely or cooperatively by the Forest Service, Bureau of Indian Affairs or the Soil Conservation Service. The Bureau of Land Management participated in the Powder River survey as part of its pilot study on soil survey. Areas being mapped by the Bureau of Indian Affairs are convered to Standard Soil Surveys by the SCS.

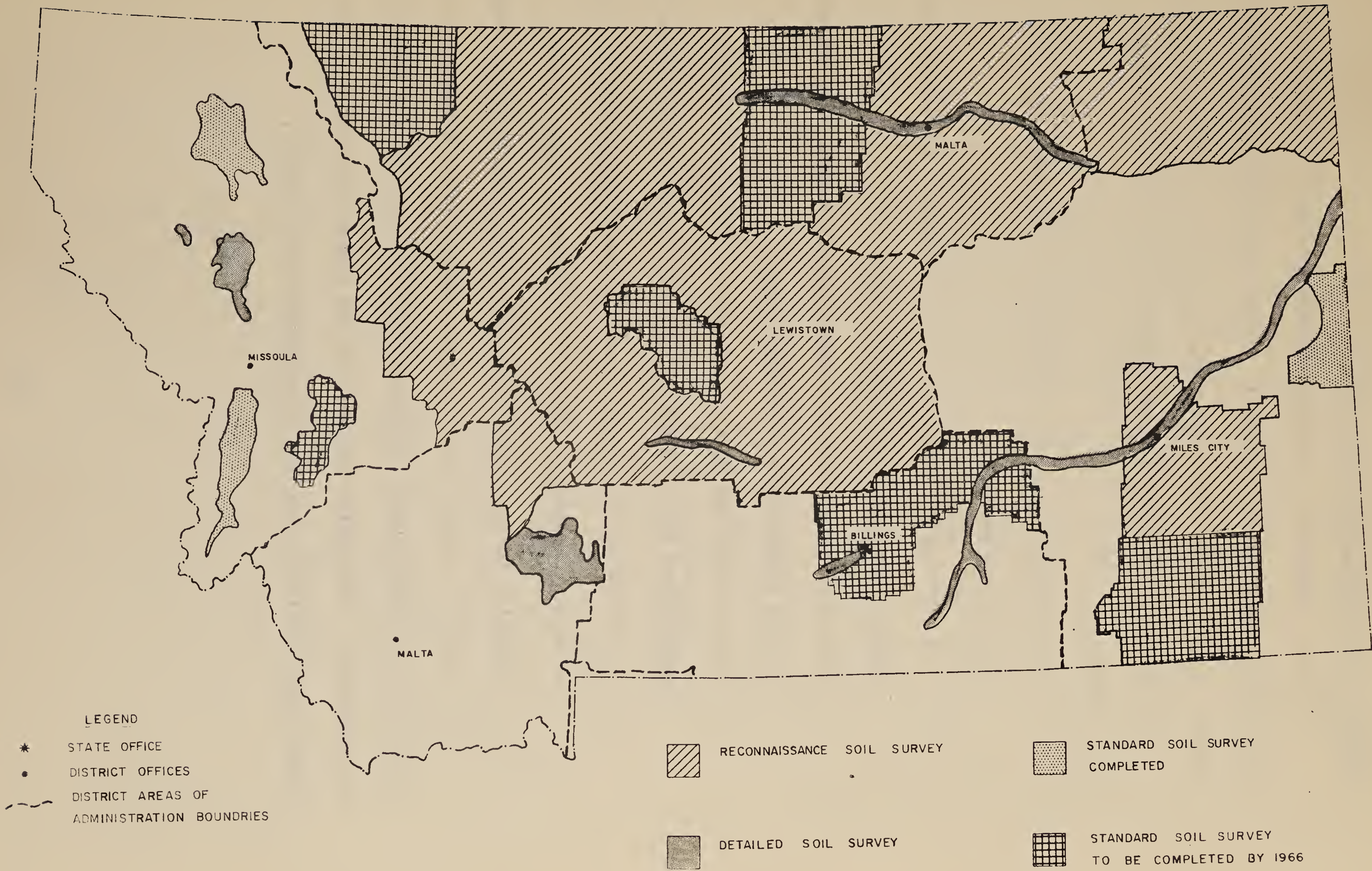
Other areas in the state are being block soil mapped and will be published at a later date. Some of the mapping is being done on a farm to farm basis by the SCS and the information used in their farm planning program.

During 1962, agencies cooperating in soil surveys reported the following acres mapped in Montana.

	Acres
Soil Conservation Service	1,900,000
Bureau of Indian Affairs	750,000 *
Bureau of Land Management	180,000
Forest Service	140,000

* Area mapped by BIA and converted to Standard Soil Survey by SCS

SOIL SURVEY PROGRESS IN MONTANA



Montana Soil Survey Publication Areas

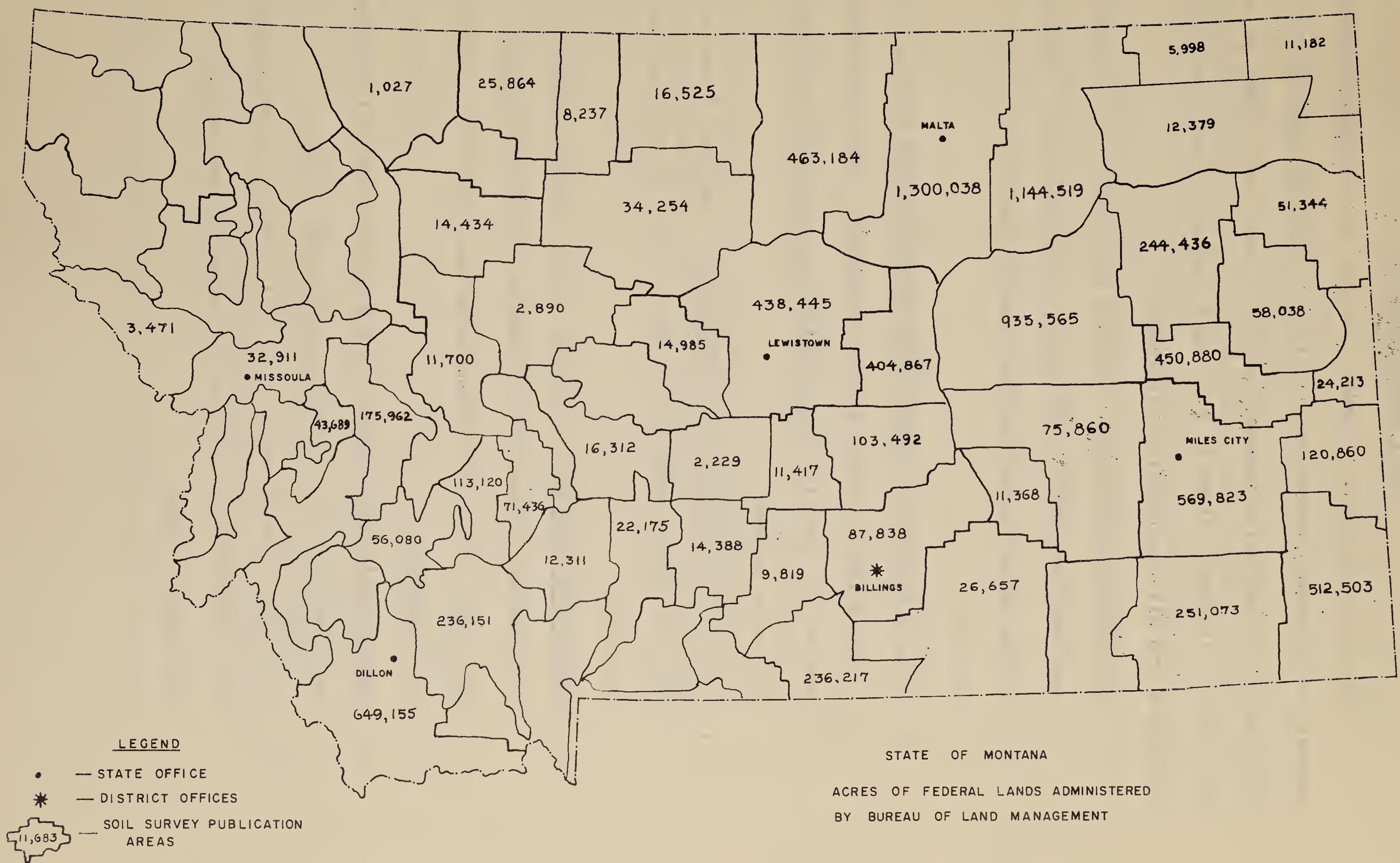
The Soil Conservation Service has divided Montana into the Soil Survey Publication Areas (see map). Three areas have been published. Current plans call for the completion of one to two areas each year.

The main criteria for setting up these areas are: (SCS Soils Memorandum 41)

1. The boundaries must be established in collaboration with cooperating agencies.
2. Each publication area must be an economically feasible unit, neither very small and not too large.
3. Boundaries of publication areas must be established to avoid leaving unpublished slivers or gaps.
4. Publication areas must be established in ways to avoid unnecessary delay in publishing soil surveys of immediate importance.
5. Significant overlapping of publication areas should be avoided as much as possible. In some instances however, the more recent intensive surveys will overlap an older less intensive survey.

The boundaries in Montana were established before the Bureau became interested in soil surveys; therefore, they do not take BLM priorities into consideration. Boundaries can possibly be changed to suit our needs better when priority areas are established by the Bureau.

SOIL SURVEY PUBLICATION AREAS



Soil Survey Work Plan

If the Bureau decides to conduct its own soil surveys the type of cooperative agreement needed will be little different than what is provided for by SCS Soils Memorandum (SCS-4, Rev. Jan., 1959) on survey work plans. The major items to be agreed upon are covered in this memorandum and will include the following:

1. Name of the survey area - Several work plans can be prepared for any area reasonably large enough for publication. This could be a Soil Conservation District, county, part of a county, or several counties.
2. Size of the area - Acres of the different land status. Estimate of the acreage in each mapping intensity, high, medium or low. Most of the area in Bureau administration will be medium or low intensity mapping.
3. Location and description of the area - Important features of the area are given, particularly those having an influence on mapping intensity.
4. Cooperating agencies - The name of all agencies involved, amount of funds and personnel and equipment furnished by each.
5. Base maps - The kind and scale of base maps to be used in the field mapping.
6. General publication plans - Scale at which the soil maps will be published, the kind of maps and how many copies.
7. Leadership - Who or what agency will assume responsibility for party leadership and prepare and maintain the complete descriptive legend.

8. Soil report - What agency will be responsible for writing the soils report.

Amendments to the survey work plan can be made anytime a significant change is made in the specifications. According to information found in the SCS Soils Memorandums, the work plan is not legally binding upon those agencies signing it. An example of the forms used by the SCS for the survey work plan and amendments to the plan can be found in the Appendix.

Guide for Cooperative Working Arrangements

Some details are not specifically covered in the survey work plan. A guide, similar to the one between the Bureau of Indian Affairs and the Soil Conservation Service, (see Appendix) on cooperative working arrangements may be useful. Some of the details to be covered in such a guide would be as follows:

1. Whose responsibility is it to coordinate the soil survey work of the BLM and the SCS at the field level. This function would probably be between the BLM State Director and the SCS State Conservationist. It would also be their responsibility to determine which survey areas have the highest priority for soil survey completion and publication. If the Bureau decides to make their own soil surveys they would naturally have more control over survey priority.
2. Provisions must be made so that the agency responsible for the

survey meets all requirements of the other agencies involved. For example, if the Bureau of Land Management determines it does not wish to assume responsibility for publishing the survey report, arrangements must be made for the collection of the necessary data needed to prepare the manuscript for the published report. It may be necessary for the SCS to assign one of their soil scientists to collect the type of information they need. The contributions of each agency should be given full recognition in the published report.

3. Terminology of the report should be uniform between agencies in the presentation of the soil and vegetative data to the general public. Kinds of soil, grouped for different purposes, such as land-capability groupings and range sites are a good example where uniform terminology is needed. These groupings should be readily available and easily understood by those who need it.

4. The State Director of the Bureau of Land Management and the State Conservationist of the Soil Conservation Service or their representatives, and other agencies interested in soils should meet at least once a year. At this conference, survey plans should be reviewed, correlation problems discussed and research needs studied. Consideration should be given as to the personnel and facilities available for assignment to cooperative soils work. Means for facilitating inter-agency coordination of mapping legends, progress and final field reviews and survey techniques

should be discussed.

Any problems of interest only to the BLM and the SCS should be resolved at a meeting between agency heads or their representatives. It is best that problems be resolved as soon as possible before any appreciable amount of field mapping has been done.

5. A soil survey work plan should be developed for each survey area. No two areas are exactly alike. Map detail, scale, land ownership patterns and survey purpose will vary from one area to another. Major items to be included in the agreement are discussed in the section of the report on "Soil Survey Work Plans".

   In survey areas of "checker-board" land ownership pattern it should be resolved who will initiate the work plan and assume leadership of the survey. Ordinarily the agency having the greatest immediate need for the soils data will assume this responsibility.

Methods of Obtaining Soils Information

1. Rely on the Soil Conservation Service as we have in the past to provide the necessary soils information.
2. Contract with the SCS to make the Bureau soil surveys. This method would require financial contributions to enable the SCS to hire additional personnel needed for our surveys. Priority

areas to be soil surveyed and their completion dates can be established.

3. The Bureau can cooperate in combined BLM-SCS soil survey teams, similar to the Montana soil survey pilot study.

4. The Bureau can employ soil scientists and make its own soil surveys. It should be stressed that close cooperation with the SCS will be necessary in many phases of the survey particularly in the initial review, progress field reviews, soil correlation, and soils training.

Each of these four methods of obtaining soils information has some merit, each has some disadvantages.

Method #1 - relying on the SCS as we have in the past. There probably is less merit and more disadvantages in this method than in the others. High priority areas of the BLM are usually low priority for the SCS. Under the present system of obtaining soils information it may take 30 to 40 years in Montana for some of our high priority areas to be mapped. Some areas may never be mapped unless the SCS receives financial or personnel assistance. A similar situation probably exists over much of the west where there are large blocks of federal land.

One of the greatest problems under the present system of obtaining soils information, and it will be a problem with other methods, is the lack of interest in the soil. Many Bureau people are not aware of the value of soils information. They wouldn't use the information if it were available to them.

Method #2 - contracting our surveys to the SCS, has a great many advantages. The biggest being that the Bureau would not need to acquire the great many personnel needed to carry on a soil survey program. The SCS are geared for soils work by having the soil laboratories, cartographic facilities, soil scientists and the experience of making surveys. The SCS can collect the basic soils data and any other information they would need for writing the soils report. From this information the BLM can make interpretation for their uses.

Method #3 - combined BLM-SCS survey teams may work very well in areas of checkerboard land pattern. These areas however may be low priority for the Bureau and not mapped for some time. The land would eventually be mapped by the SCS as a normal part of their survey program.

Method #4 - the Bureau making its own surveys has considerable merit. A soil survey program administered by the Bureau will be better coordinated to our needs. Soil scientists working closely with other Bureau personnel will become more aware of our needs and uses of soils information. This close contact will help range men, engineers, lands men and others become more soils conscious and make greater and better use of soils information.

It will be expensive, qualified overhead personnel will be required, and it may take years to build a well functioning soil survey organization.

PART VI

RECOMMENDATIONS

1. The Bureau of Land Management should enter into a cooperative agreement with the Soil Conservation Service to cover cooperative soil survey work. The Bureau as a major federal land administering agency has a responsibility to cooperate in the National Cooperative Soil Survey. Presently it is the only major land administering agency not actively engaged in soil survey activities.

2. If the Bureau decides to make their own soil surveys they should make them according to the Soil Conservation Service standards. Surveys by both agencies should correlate with each other to prevent duplication of effort and encourage exchange of information.

3. Interpretations should not be worked into the classification system. The soil must be classified according to genetic and morphological features of the soil. A system of soil classification based on limited knowledge of the soil or one for limited purposes may soon be useless or misleading.

4. An information program should be initiated to aid Bureau personnel in becoming more aware of the soil, and how to use soils information in planning, land classification and other activities.

PART VII

APPENDIX

Page

HORIZON BOUNDARIES

Horizon boundaries vary (1) in distinctness, and (2) in surface topography. Some boundaries are clear and sharp, as those between A_2 and B_2 horizons in most solodized-Solonetz and well-developed Podzols. Again they may be diffuse, with one horizon gradually merging into another, as between the A_1 and A_3 of Chernozem or the B_2 and B_3 of many Latosols. With these diffuse horizons, the location of the boundary requires time-consuming comparisons of small samples of soil from various parts of the profile until the midpoints are established. Small markers can be inserted until all horizons of the profile are worked out; then measurements can be taken; and finally the individual horizons can be described and sampled. Sampling can often begin with the lowest horizon to good advantage.

The distinction of the horizons to the observer depends partly upon the contrast between them—some adjacent ones are highly contrasting in several features—and partly upon the width of the boundary itself or the amount of the profile in the transition between one horizon and the next. The characteristic widths of boundaries between soil horizons may be described as (1) *abrupt*, if less than 1 inch wide; (2) *clear*, if about 1 to 2½ inches wide; (3) *gradual*, if 2½ to 5 inches wide; and (4) *diffuse*, if more than 5 inches wide.

The topography of different soil horizons varies, as well as their distinctness. Although observations of soil horizons are made in profiles or sections, and so photographed or sketched, we must continually recall that they are not "bands" (or literally "horizons" as that word is understood in everyday speech) but rather three-dimensional layers that may be smooth or exceedingly irregular. Horizon boundaries may thus be described as (1) *smooth*, if nearly a plane; (2) *wavy* or undulating, if pockets are wider than their depth; (3) *irregular*, if irregular pockets are deeper than their width; and (4) *broken*, if parts of the horizon are unconnected with other parts, as the B_2 in the limestone cracks of a truncated Terra Rossa.

COLOR PATTERNS

Nearly every soil profile consists of several horizons differing in color. For every soil examined and described in the field, the complete color profile should be presented. A single horizon may be uniform in color or it may be streaked, spotted, variegated, or mottled in many ways. Local accumulations of lime or organic matter may produce a spotted appearance. Streaks or tongues of color may result from the seeping downward of colloids, organic matter, or iron compounds from overlying horizons. Certain combinations of mottled colors, mainly the grays and browns, indicate impeded drainage. The word "mottled" means marked with spots of color. Some mottled colors occur unassociated with poor drainage, either past or present. A mottled or variegated pattern of colors occurs in many soil horizons and especially in parent materials that are not completely weathered.

Mottling in soils is described by noting: (1) The color of the matrix and the color, or colors, of the principal mottles, and (2) the pattern of the mottling. The color of the mottles may be defined by using the Munsell notation, as with other soil masses; but usually it is sufficient and even better to use the standard linguistic equivalents, since precise measurement of the color of the mottles is rarely significant. In fact, descriptions of soil horizons containing several Munsell notations are difficult to read rapidly.

The pattern of mottles can be conveniently described by three sets of notations: contrast, abundance, and size.[4]

Contrast.—Contrast may be described as *faint*, *distinct*, or *prominent* as follows:

Faint: Indistinct mottles are evident and recognizable only with close examination. Soil colors in both the matrix and mottles have closely related hues and chromas.

Distinct: Although not striking, the mottles are readily seen. The hue, value, and chroma of the matrix are easily distinguished from those of the mottles. They may vary as much as one or two hues or several units in chroma or value. The pattern may be one of a continuous matrix with mottles or one of mixtures of two or more colors.

Prominent: The conspicuous mottles are obvious and mottling is one of the outstanding features of the horizon. Hue, chroma, and value may be several units apart. The pattern may be one of a continuous matrix with contrasting mottles or one of mixtures of two or more colors.

Abundance.—Abundance of mottles can be indicated in three general classes as: *few*, *common*, and *many*, based upon the relative amount of mottled surface in the unit area of the exposed soil horizon, as follows:[5]

Few: Mottles occupy less than about 2 percent of the exposed surface.

Common: Mottles occupy about 2 to 20 percent of the exposed surface.

Many: Mottles occupy more than 20 percent of the exposed surface. This last class can be further subdivided according to whether (a) the mottles set in a definite matrix or (b) there is no clear matrix color.

Size.—Size refers to the approximate diameters of individual mottles. Three relative size classes can be used as follows:

Fine: Mottles less than 5 mm. in diameter along the greatest dimension.

Medium: Mottles range between 5 and 15 mm. in diameter along the greatest dimension.

Coarse: Mottles are greater than 15 mm. in diameter along the greatest dimension.

In the detailed examination of some soil horizons, it may be necessary to add still further notes on the mottling to indicate whether or not the boundaries of the mottles are sharp (knife-edge), clear (less than 2 mm. wide), or diffuse (more than 2 mm. wide). Although many mottles are roughly circular in cross-section, others are elongated and merge into streaks or tongues. Although, normally, mottling carries no inferences of differences in texture as compared to the matrix, many soils show mottling in a freshly exposed horizon because of the slicing of incipient concretions.

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[4] This discussion is based on a recent paper: SIMONSON, R. W. DESCRIPTION OF MOTTLING IN SOILS. Soil Science. 7: 187–192. 1951.

[5] The suggested limits are tentative only. More research is needed to establish the most useful size classes and number of classes.

In soil descriptions the mottling can be most conveniently described by describing the mottles as to abundance, size, contrast, and color, such as, ". . . brown silt loam with few, fine, distinct reddish-brown and dark-gray mottles."

In verbal descriptions of soil mottling intended for the general reader, part of the detail needed in detailed soil morphology and correlation may be omitted. Thus, starting with the classes according to abundance, descriptions may be written as follows:

1. *Few:* ". . . brown silt loam, slightly mottled with red and yellow."
2. *Common:* ". . . brown silt loam, mottled with red and yellow."
3. *Many:*
   (a) If the matrix is clearly apparent: ". . . brown silt loam, highly mottled with red and yellow."
   (b) If no clear matrix exists: ". . . mottled red, yellow, and brown silt loam."

If contrast is not clearly shown by the color names, "faintly" or "prominently" may be added. Faint mottling can be implied as ". . . brown silt loam, mottled with shades."

If size is important "finely" or "coarsely" may be added, as ". . . coarsely mottled red and yellow clay", or ". . . brown silt loam finely and slightly mottled with reddish brown." Usually such distinctions are more confusing than helpful to the lay reader.

In the description of soil color, special notice should be taken of any relationships between the color pattern and structure or porosity. Structural aggregates in the soil must be broken to determine whether the color is uniform throughout. The black or dark-brown surface color of soil granules is often due to a thin coating, though the basic color of the soil material is brown or yellow. When such granules are crushed, the mass of soil is lighter in color than the original surfaces of the aggregates. Marked contrast between the color of the soil aggregates and the color of the soil when crushed is common. Coatings of red color often cover structural particles or sand grains; and a gray color may be due to a thin film of leached soil around darker aggregates.

EFFECTS OF MOISTURE

Soil color changes with the moisture content, very markedly in some soils and comparatively little in others. Between dry and moist, soil colors commonly are darker by ½ to 3 steps in value and may change from −½ to +2 steps in chroma. Seldom are they different in hue. Some of the largest differences in value between the dry and moist colors occur in gray and grayish-brown horizons having moderate to moderately low contents of organic matter.

Reproducible quantitative measurements of color are obtained at two moisture contents: (1) Air dry, and (2) field capacity. The latter may be obtained with sufficient accuracy for color measurements by moistening a sample and reading the color as soon as visible moisture films have disappeared. Both the dry and the moist colors are important. In most notes and soil descriptions, unless stated otherwise, colors are given for moist soils. Comparisons of color among widely separated soils are facilitated by using the color designation of freshly broken surfaces of air-dry samples. Official descriptions for technical use, such as series descriptions, should include the moist colors, and preferably, both dry and moist colors if significantly unlike.

DETERMINATION OF SOIL COLOR

Soil colors are most conveniently measured by comparison with a color chart. The one generally used with soil is a modification of the Munsell color chart and includes only that portion needed for soil colors, about one-fifth of the entire range of color.[6] It consists of some 175 different colored papers, or chips, systematically arranged, according to their Munsel notations, on cards carried in a loose-leaf notebook. The arrangement is by *hue*, *value*, and *chroma*—the three simple variables that combine to give all colors. *Hue* is the dominant spectral (rainbow) color; it is related to the dominant wavelength of the light. *Value* refers to the relative lightness of color and is a function (approximately the square root) of the total amount of light. *Chroma* (sometimes called saturation) is the relative purity or strength of the spectral color and increases with decreasing grayness.

In the soil color chart, all colors on a given card are of a constant hue, designated by the symbol in the upper right-hand corner of the card. Vertically, the colors become successively lighter by visually equal steps; their value increases. Horizontally, they increase in chroma to the right and become grayer to the left. The value and chroma of each color in the chart is printed immediately beneath the color. The first number is the value, and the second is the chroma. As arranged in the chart the colors form three scales: (1) Radial, or from one card to the next, in hue; (2) vertical in value; and (3) horizontal in chroma.

The nomenclature for soil color consists of two complementary systems: (1) Color names, and (2) the Munsell notation of color. Neither of these alone is adequate for all purposes. The color names are employed in all descriptions for publication and for general use. The Munsell notation is used to supplement the color names wherever greater precision is needed, as a convenient abbreviation in field descriptions, for expression of the specific relations between colors, and for statistical treatment of color data. The Munsell notation is especially useful for international correlation, since no translation of color names is needed. The names for soil colors are common terms now so defined as to obtain uniformity and yet accord, as nearly as possible, with past usage by soil scientists. Bizarre names like "rusty brown," "tan," "mouse gray," "lemon yellow," and "chocolate brown" should never be used.

The soil color names and their limits are given in the name-diagrams, figures 30 to 36.

The Munsell notation for color consists of separate notations for hue, value, and chroma, which are combined in that order to form the color designation. The symbol for hue is the letter abbreviation of the color of the rainbow (R for red, YR for yellow-red, or orange, Y for yellow) preceded by numbers from 0 to 10. Within each letter range, the hue becomes more yellow and less red as the numbers increase. The middle of the letter range is at 5; the zero point coincides with the 10 point of the next redder hue. Thus 5YR is in the middle of the yellow-red hue, which extends from 10R (zero YR) to 10YR (zero Y).

The notation for value consists of numbers from 0, for absolute black, to 10, for absolute white. Thus a color of value 5/ is visually midway between absolute white and absolute black. One of value 6/ is slightly less dark, 60 percent of the way from black to white, and midway between values of 5/ and 7/.

The notation for chroma consists of numbers beginning at 0 for neutral grays and increasing at equal intervals to a maximum of about 20, which is never really approached in soil. For absolute achromatic colors (pure grays, white, and black), which have zero chroma and no hue, the letter N (neutral) takes the place of a hue designation.

In writing the Munsell notation, the order is hue, value, chroma, with a space between the hue letter and the succeeding value number, and a virgule between the two numbers for value and chroma. If expression beyond the whole numbers is desired, decimals are always used, never fractions. Thus the notation for a color of hue 5YR, value 5, chroma 6, is 5YR 5/6, a yellowish-red. The notation for a color midway between the 5YR 5/6 and 5YR 6/6 chips is 5YR 5.5/6; for one midway between 2.5YR 5/6 and 5YR 6/8, it is 3.75YR 5.5/7. The notation is decimal and capable of expressing any degree of refinement desired. Since color determinations cannot be made precisely in the field—generally no closer than half the interval between colors in the chart—expression of color should ordinarily be to the nearest color chip.

In using the color chart, accurate comparison is obtained by holding the soil sample above the color chips being compared. Rarely will the color of the sample be *perfectly* matched by any color in the chart. The probability of having a perfect matching of the sample color is less than one in one hundred. It should be evident, however, which colors the sample lies between, and which is the closest match. The principal difficulties encountered in using the soil color chart are (1) in selecting the appropriate hue card, (2) in determining colors that are intermediate between the hues

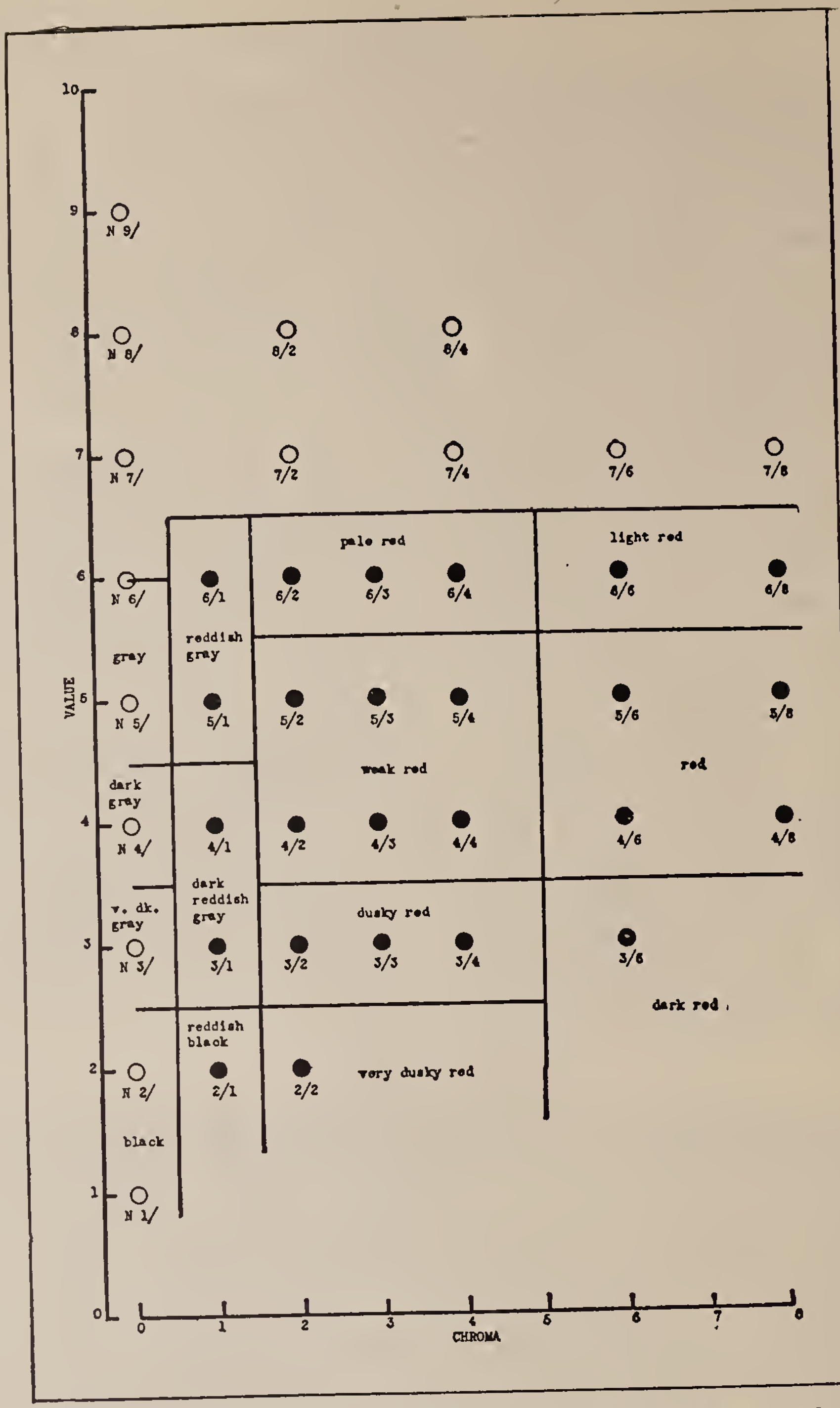

FIGURE 30.—Soil color names for several combinations of value and chroma and hue 10R.

in the chart, and (3) in distinguishing between value and chroma where chromas are strong. In addition, the chart does not include some extreme dark, strong (low value, high chroma) colors occasionally encountered in moist soils. With experience, these extreme colors lying outside the range of the chart can be estimated. Then too, the ability to sense color differences varies among people, even among those not regarded as color blind.

While important details should be given, long involved designations of color should generally be avoided, especially with variegated or mottled colors. In these, only the extreme or dominant colors need be stated. Similarly, in giving the color names and Munsell notations for both the dry and moist colors, an abbreviated form, such as "reddish brown (5YR 4/4; 3/4, moist)," simplifies the statement.

By attempting detail beyond the allowable accuracy of field observations and sample selection, one may easily make poorer soil descriptions than by expressing the dominant color simply. In all descriptions, terms other than the ones given on these charts should be used only in rare instances, and then only as supplemental expressions in parentheses where some different local usage is common.

SOIL TEXTURE, COARSE FRAGMENTS, STONINESS, AND ROCKINESS

Soil texture refers to the relative proportions of the various size groups of individual soil grains in a mass of soil. Specifically, it refers to the proportions of clay, silt, and sand below 2 millimeters in diameter.

The presence of coarse particles larger than very coarse sand

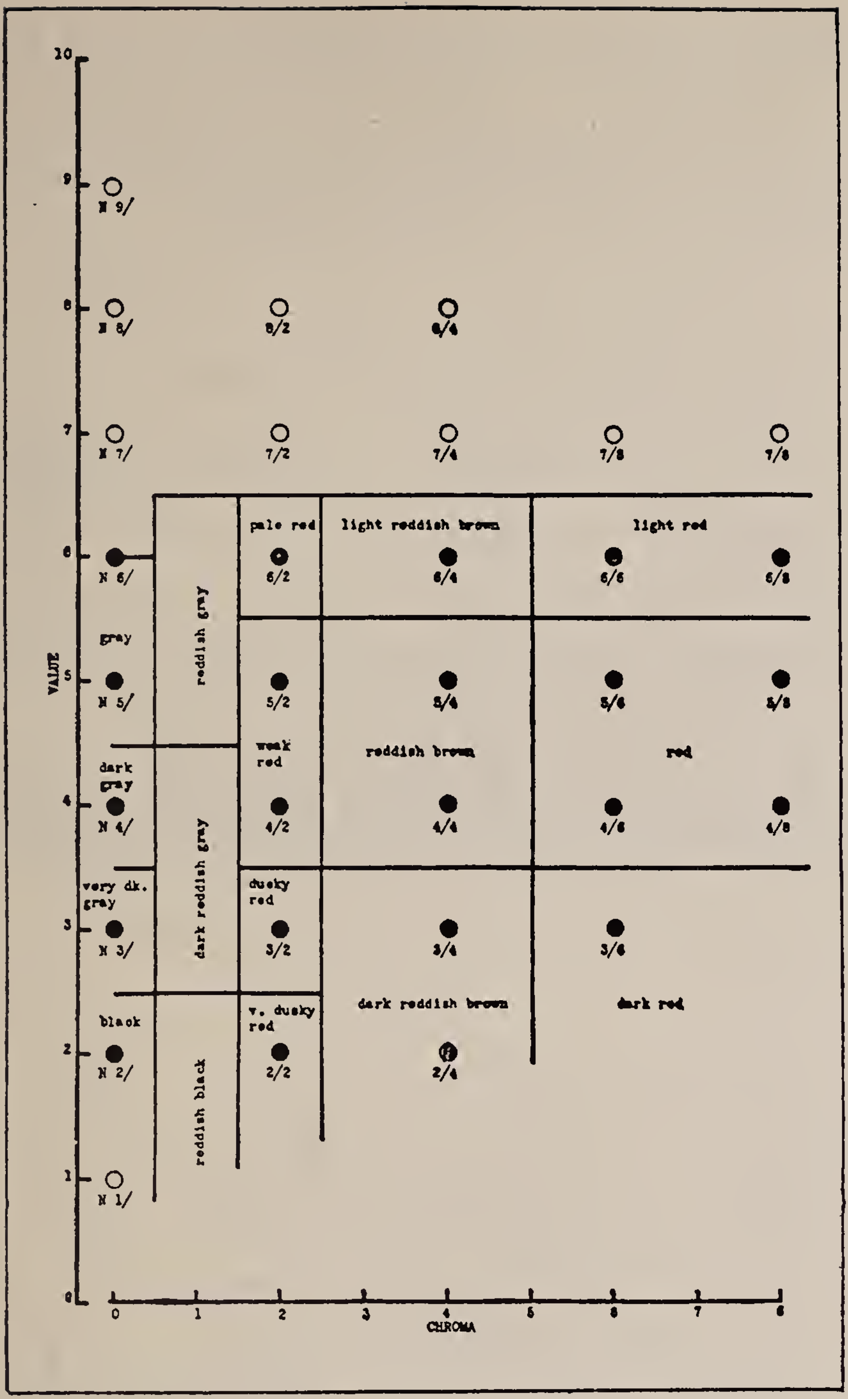

FIGURE 31.—Soil color names for several combinations of value and chroma and hue 2.5YR.

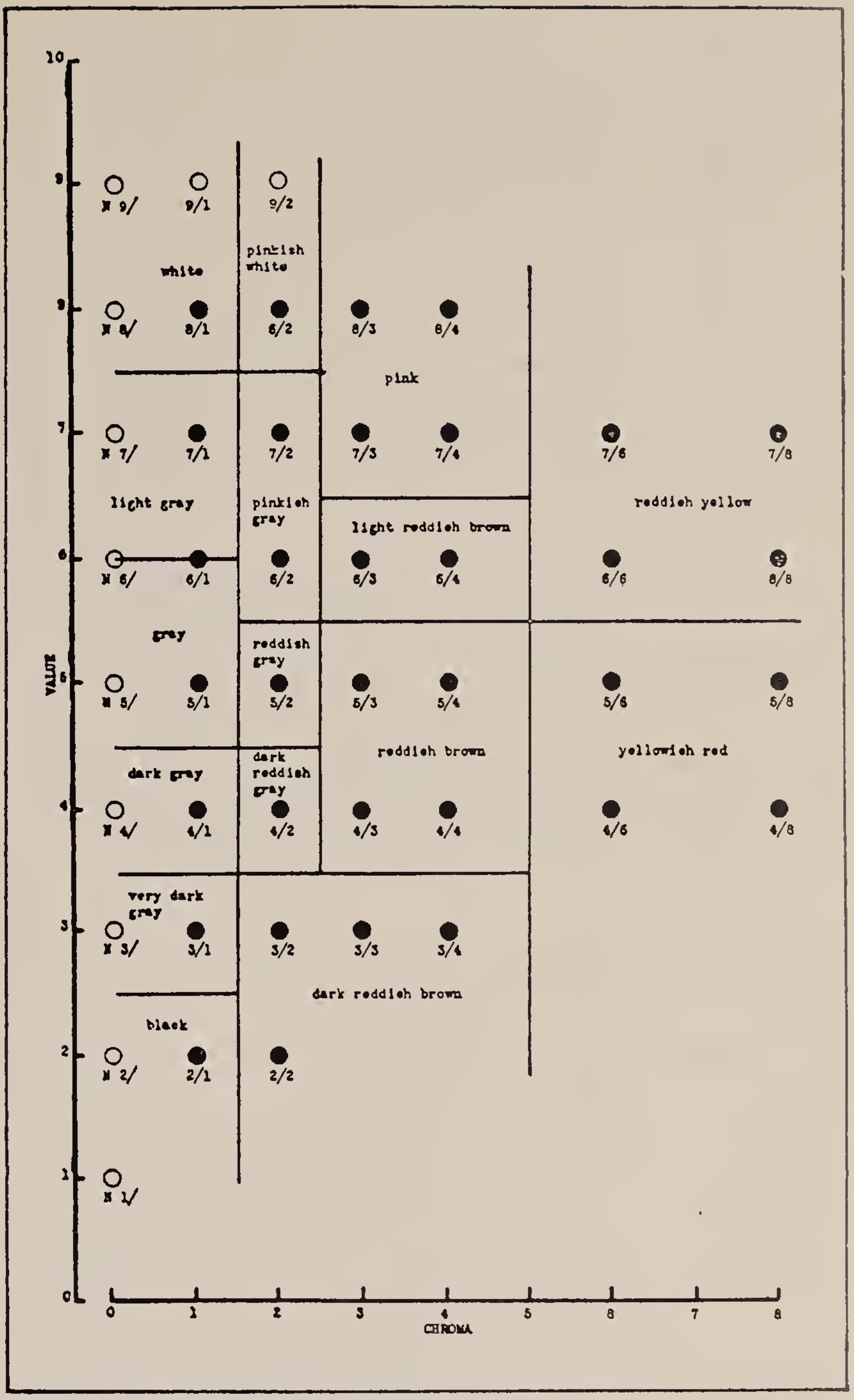

FIGURE 32.—Soil color names for several combinations of value and chroma and hue 5YR.

(or 2 mm.) and smaller than 10 inches is recognized by modifiers of textural class names, like *gravelly* sandy loam or *cobbly* loam.

General classes of still larger particles—stones or rock outcrops—are defined in terms of the influence they have on soil use, and in specific physical terms for individual soil series. Although distinctions within a type, series, family, or great soil group according to stoniness or rockiness are *phases*, these are indicated in soil types by an additional adjective added to the soil class name. Thus, Gloucester stony loam and Gloucester very stony loam are two phases of Gloucester loam which could be written more accurately and more clumsily Gloucester loam, stony phase, and Gloucester loam, very stony phase.

Actually, of course, sharp distinctions among the size groups of particles are more or less arbitrary. They have been arrived at after many, many trials in developing classes that can be used consistently and conveniently to define soil classificational and mapping units in such ways that they can be given the most specific interpretations.

The discussion of particle size is therefore presented under three principal headings: (1) The designation of soil textural class based primarily upon the proportion of clay, silt, and sand; (2) the definition of groups of coarse fragments having diameters less than 10 inches that may be regarded as a part of the soil mass and modify the textural class; and (3) the definition of classes of stoniness and rockiness for stones over 10 inches in diameter and for bedrock not considered a part of the soil mass.

SOIL TEXTURAL CLASS

The texture of a soil horizon is, perhaps, its most nearly permanent characteristic. Structure can be quickly modified by management. Often the texture of the plowed layer of an arable soil is modified, not by changes within the surface layer, but by the removal of surface horizons and the development of a new surface soil from a lower natural horizon of different texture, or by the addition of a new surface horizon, say of wind-blown sand or of silt loam settling out of muddy irrigation water. Soil blowing during drought may change soil texture by removing the fine particles from the exposed soil, leaving the surface soil richer in sand and coarse fragments than before.

Although texture is a seemingly simple basic concept in soil science, its consistent application has not been easy. Texture is so basic that terms like sand, clay, and loam are very old indeed. Since both consistence and structure are very important properties related partly to texture, the textural terms, as used earlier, had some connotations of these qualities as well as of texture. As long as their use was confined to soils in Britain and in the eastern part of the United States, the lack of correspondence between field designations of soil textural class and actual size distribution as shown by mechanical analysis was not obviously great. Yet structure and consistence depend on the kind and condition of the clay as well as on the amount of clay, on other soil constituents, and on the living tissue in the soil. As soil scientists began to deal with all soils, many of which are quite unlike the podzolized soils of the temperate forested regions, it became clear that structure, consistence, and texture had to be measured separately. Then too, early dispersion methods were so inadequate that fine granules of clay were actually reported as silt or sand.

Common sources of confusion and error are the agricultural connotations that were associated with the soil textural class names as formerly used. Clay soils were supposed to be sticky and easily puddled; sand soils were supposed to be loose, struc-

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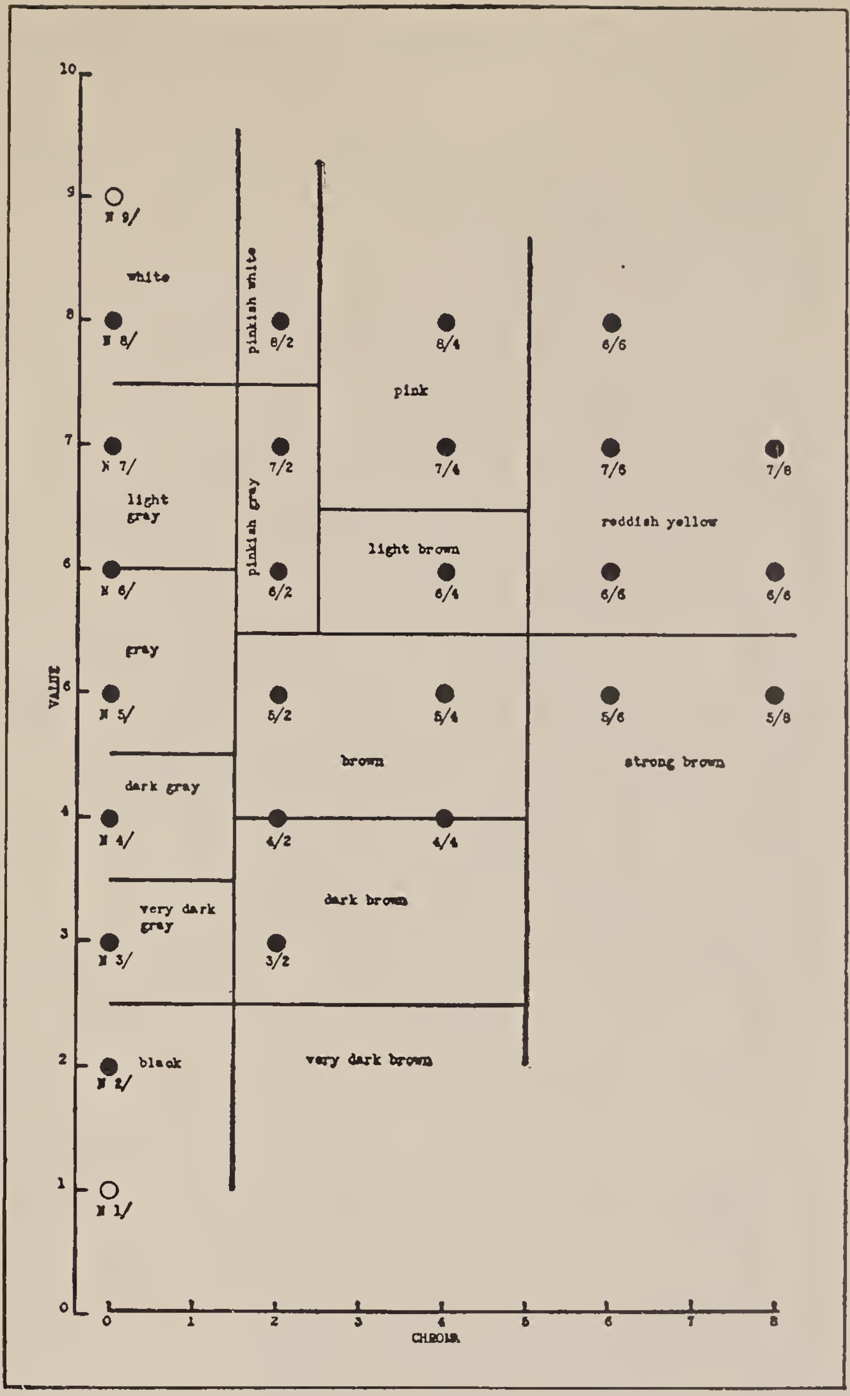

FIGURE 33.—Soil color names for several combinations of value and chroma and hue 7.5YR.

tureless, and droughty. Such connotations do not hold generally, however, and must be dissociated from general soil textural class names. Among some soil groups, clay soils are sticky and easily puddled, but among others they are not at all. Many sand soils are loose, structureless, and droughty, but some are not. As with each other soil characteristic, no direct relationship that can be applied generally to all soils exists between soil textural class and fertility, productivity, or other inferred qualities. To make such inferences we must also know the other important soil characteristics. Unfortunately, these erroneous correlations are well fixed in some textbooks and other books about soils for farmers and gardeners. Within the universe that the authors of these books actually consider, say Britain and the northeastern part of the United States, the correlations may be approximately correct for most soils; but the writers do not thus clearly limit their universe. As applied to the arctic, the tropics, and the desert they are often seriously wrong, even for the principal soils. Standardization of soil textural class names in terms of size distribution alone is clearly essential if soils of widely different genetic groups are to be compared.

SOIL SEPARATES

Soil separates are the individual size-groups of mineral particles. Sometimes the large sizes—coarse fragments—are included, but usually the groups of particles below 2 mm. in diameter are the only ones called soil separates. Since so many of the chemical and physical reactions in soils occur mainly on the surface of the grains, the fine part is most important. Only 4 pounds of dry clay particles having a diameter of 0.001 mm. have a total surface area of about an acre. The amount of surface exposed per unit weight drops very rapidly with increasing diameter until above 0.005 mm. in diameter the differences are small.

Two schemes are in common use: (1) The International system proposed by Atterberg and (2) the scheme used in the United States Department of Agriculture, which is now essentially consistent with the International system but makes more separations. Mechanical analyses of soils in the Department are reported in both systems as shown in table 2 and figure 37.

TABLE 2.—*Size limits of soil separates from two schemes of analysis*

U. S. Department of Agriculture scheme		International scheme	
Name of separate	Diameter (range)	Fraction	Diameter (range)
	Millimeters		*Millimeters*
Very coarse sand[1]	2.0 -1.0		
Coarse sand	1.0 - .5	I	2.0–0.2
Medium sand	.5 - .25		
Fine sand	.25- .10	II	.20–.02
Very fine sand	.10- .05		
Silt	.05- .002	III	.02–.002
Clay	Below .002	IV	Below .002

[1] Prior to 1947 this separate was called fine gravel. Now fine gravel is used for coarse fragments from 2 mm. to ½ inch in diameter.

TEXTURAL CLASS NAMES AND THEIR DEFINITIONS

Rarely, if ever, do soil samples consist wholly of one separate. Classes of soil texture are based on different combinations of sand, silt, and clay. The basic classes in order of increasing proportions of the fine separates are sand, loamy sand, sandy loam,

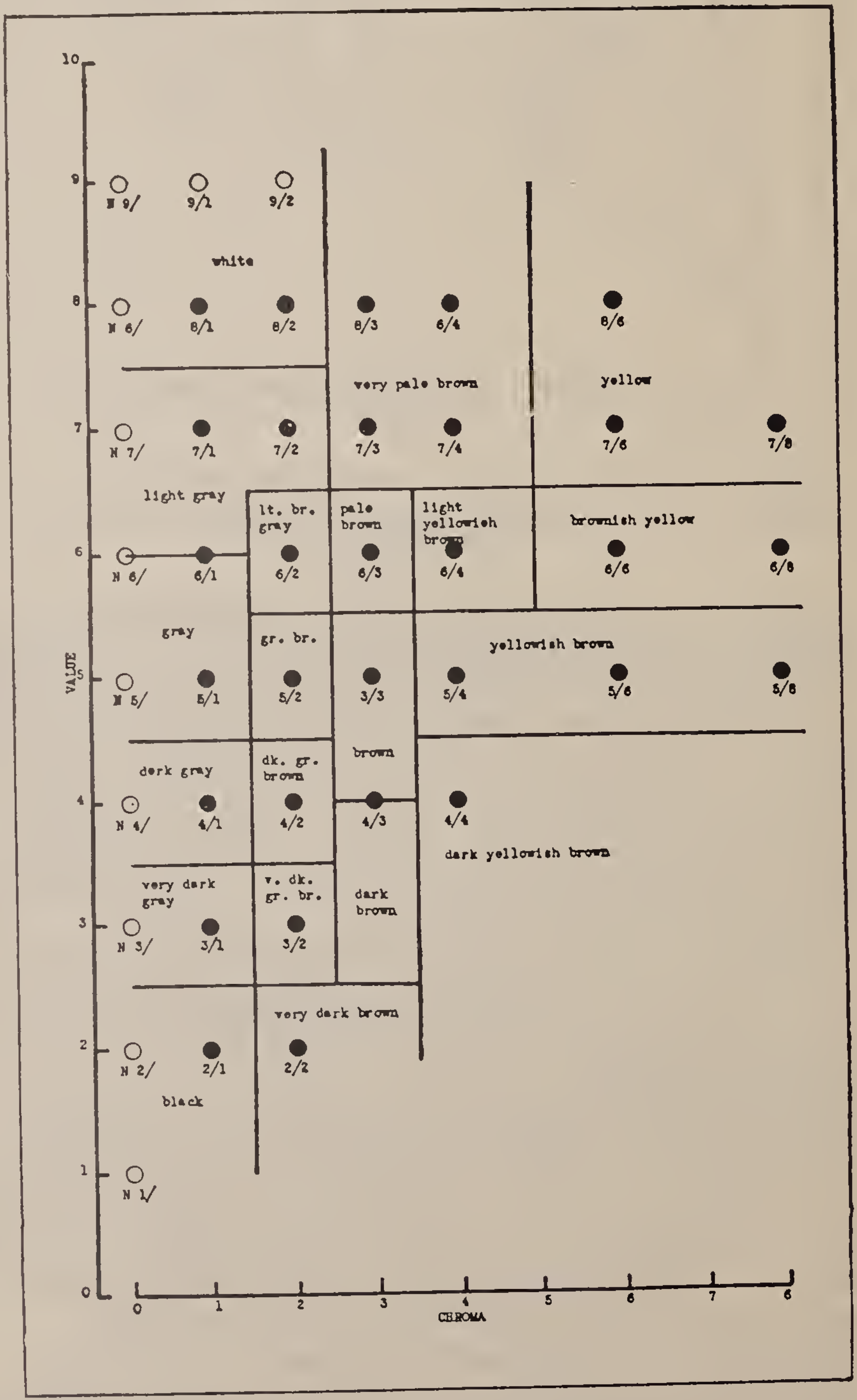

FIGURE 34.—Soil color names for several combinations of value and chroma and hue 10YR.

loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. Those with the term "sand" in the name are modified for very fine, fine, coarse, or very coarse sand.[1] In these class names the word "loam" appears. This is an old English word formerly applied to crumbly soils rich in humus. It is still used by some in that sense. In soil classification, however, it is used only in soil textural class names.[2]

The basic soil textural class names in present use are defined in terms of *size distribution* as determined by mechanical analysis in the laboratory.[3]

The definitions of these classes developed since the earlier edition of this *Manual* have resulted from long experience and much special research to establish boundaries between classes so that they have the maximum general use for soil definitions and interpretations. Using the results of this research had the effect of some nearly drastic modifications in the old definitions of class names in terms of actual percentages of sand, silt, and clay as determined in the laboratory, and some modifications in field definitions based upon feel. Whereas laboratory data from mechanical analyses were formerly regarded as general guides only to soil textural class names, they are now regarded as absolute guides to soils of the mainland of the United States. At the same time one cannot say that the standards are yet perfect. Especially may further improvements be expected in the designations used for the textural class of Tundra soils and of Latosols in which the clays generally have different mineralogical compositions from those of soils in temperate regions. Textural class names must be defined wholly in terms of size distribution, however, and not used to express differences in consistence or structure; else the names will lose their fundamental significance.

Definitions of the basic classes are set forth in graphic form in figure 38, in terms of clay, below 0.002 mm; silt, 0.002 to 0.05 mm; and sand 0.05 to 2.0 mm. Although much improved over previous charts, this one is still tentative. Those frequently interpreting laboratory data into soil textural class names will find an enlarged copy of this triangle useful. Verbal definitions of the soil textural classes, defined according to size distribution of mineral particles less than 2 millimeters in diameter, are as follows:

Sands.—Soil material that contains 85 percent or more of sand; percentage of silt, plus 1½ times the percentage of clay, shall not exceed 15.

Coarse sand: 25 percent or more very coarse and coarse sand, and less than 50 percent any other one grade of sand.

Sand: 25 percent or more very coarse, coarse, and medium sand, and less than 50 percent fine or very fine sand.

Fine sand: 50 percent or more fine sand (or) less than 25 percent very coarse, coarse, and medium sand and less than 50 percent very fine sand.

Very fine sand: 50 percent or more very fine sand.

Loamy sands.—Soil material that contains at the upper limit 85 to 90 percent sand, and the percentage of silt plus 1½ times the percentage of clay is not less than 15; at the lower limit it contains not less than 70 to 85 percent sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

[1] It will be noted that the terms "clay," "silt," "very fine sand," "fine sand," and "coarse sand" are used for both soil separates and for specific soil classes.

[2] Unfortunately, old and misleading names like "desert loams," "tropical red loams," and "brown loams" still persist as group names for soils varying widely from loam in texture.

[3] For accepted methods now in use see KILMER, V. J., and ALEXANDER, L. T. METHODS OF MAKING MECHANICAL ANALYSIS OF SOILS. Soil Sci. 68: 15–24. 1949.

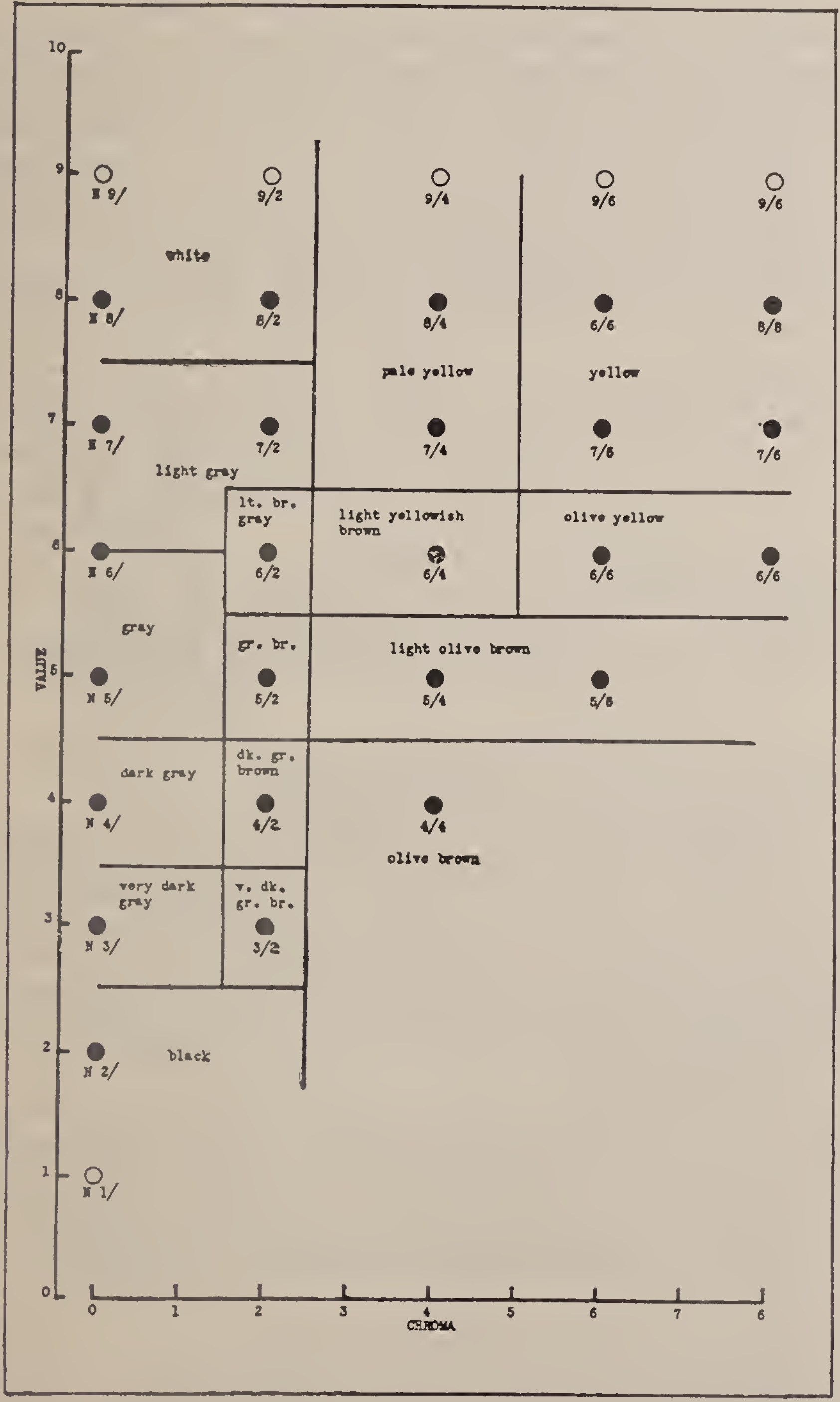

FIGURE 35.—Soil color names for several combinations of value and chroma and hue 2.5Y.

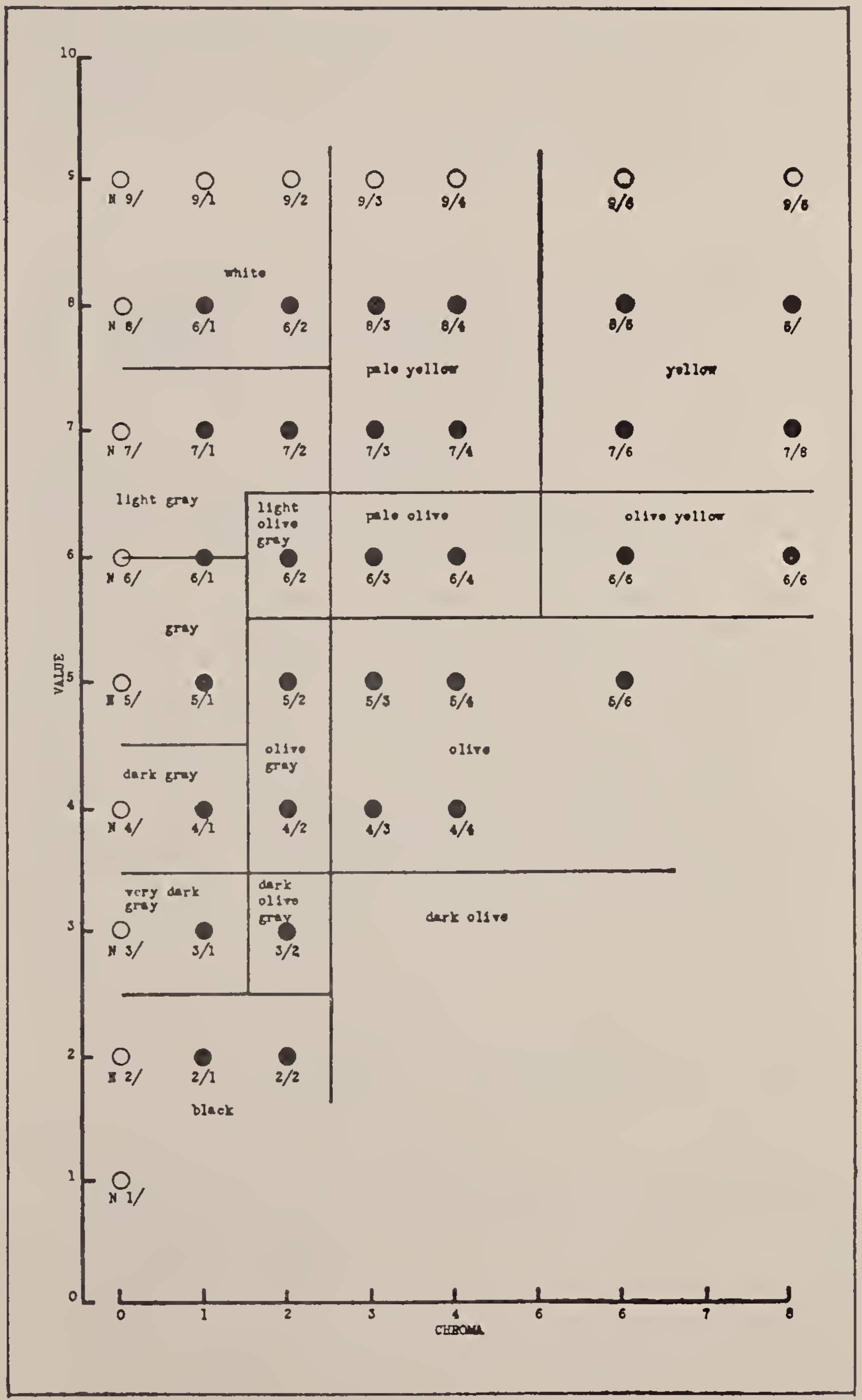

FIGURE 36.—Soil color names for several combinations of value and chroma and hue 5Y.

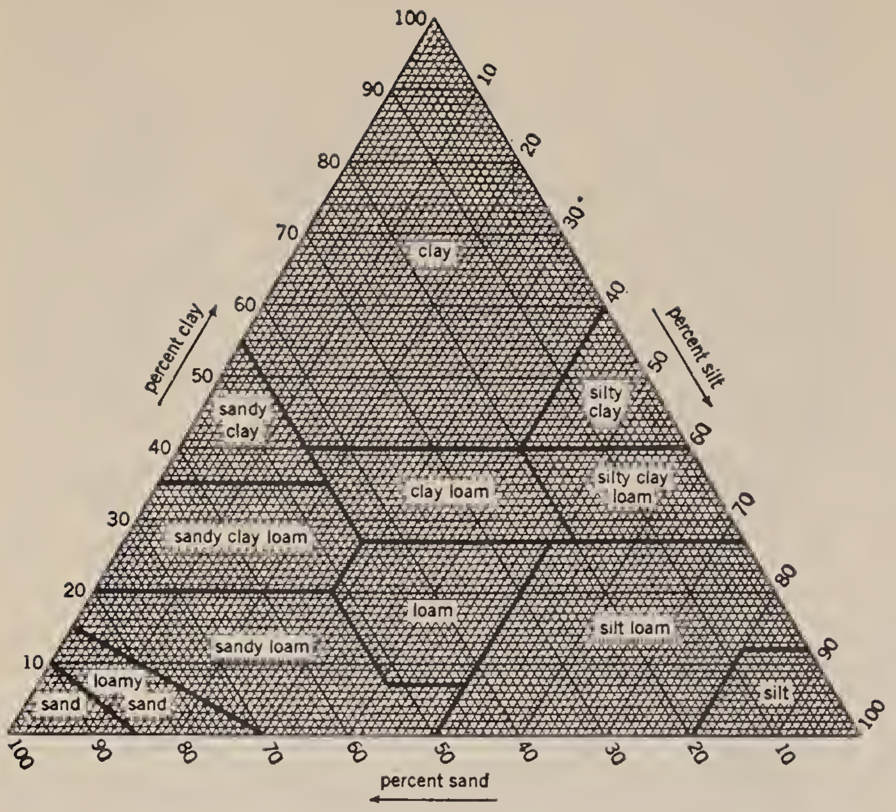

FIGURE 38.—Chart showing the percentages of clay (below 0.002 mm.), silt (0.002 to 0.05 mm.), and sand (0.05 to 2.0 mm.) in the basic soil textural classes.

Loamy coarse sand: 25 percent or more very coarse and coarse sand, and less than 50 percent any other one grade of sand.

Loamy sand: 25 percent or more very coarse, coarse, and medium sand, and less than 50 percent fine or very fine sand.

Loamy fine sand: 50 percent or more fine sand (or) less than 25 percent very coarse, coarse, and medium sand and less than 50 percent very fine sand.

Loamy very fine sand: 50 percent or more very fine sand.

Sandy loams.—Soil material that contains either 20 percent clay or less, and the percentage of silt plus twice the percentage of clay exceeds 30, and 52 percent or more sand; or less than 7 percent clay, less than 50 percent silt, and between 43 percent and 52 percent sand.

Coarse sandy loam: 25 percent or more very coarse and coarse sand and less than 50 percent any other one grade of sand.

Sandy loam: 30 percent or more very coarse, coarse, and medium sand, but less than 25 percent very coarse sand, and less than 30 percent very fine or fine sand.

Fine sandy loam: 30 percent or more fine sand and less than 30 percent very fine sand (or) between 15 and 30 percent very coarse, coarse, and medium sand.

Very fine sandy loam: 30 percent or more very fine sand (or) more than 40 percent fine and very fine sand, at least half of which is very fine sand and less than 15 percent very coarse, coarse, and medium sand.

Loam.—Soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand.

Silt loam.—Soil material that contains 50 percent or more silt and 12 to 27 percent clay (or) 50 to 80 percent silt and less than 12 percent clay.

Silt.—Soil material that contains 80 percent or more silt and less than 12 percent clay.

Sandy clay loam.—Soil material that contains 20 to 35 percent clay, less than 28 percent silt, and 45 percent or more sand.

Clay loam.—Soil material that contains 27 to 40 percent clay and 20 to 45 percent sand.

Silty clay loam.—Soil material that contains 27 to 40 percent clay and less than 20 percent sand.

Sandy clay.—Soil material that contains 35 percent or more clay and 45 percent or more sand.

Silty clay.—Soil material that contains 40 percent or more clay and 40 percent or more silt.

Clay.—Soil material that contains 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Necessarily these verbal definitions are somewhat complicated and, perhaps, not entirely adequate for unusual mixtures near the boundaries between classes. Some of the definitions are not entirely mutually exclusive, but the information needed to make them so is lacking. Departures from these definitions should be made only after careful joint research between field and laboratory scientists.

In addition to these basic soil textural class names, modified according to the size group of the sand fraction, other terms are also added as modifiers.

Muck, peat, mucky peat, and *peaty muck* are used in place of the textural class names in organic soils—muck for well-decomposed soil material, peat for raw undecomposed material, and peaty muck and mucky peat for intermediate materials. Former definitions have also specified a higher mineral content for muck than for peat. This cannot be followed, however, since many raw peats contain high amounts of mineral matter dropped from the air or washed in by water. The word "mucky" is used as an adjective on the textural class name for horizons of mineral soils, especially of Humic-Gley[4] soils that contain roughly 15 percent or more of partially decomposed organic matter. Horizons designated "mucky loam" or "mucky silt loam" are intergrades between muck and the soil textural class.

The terms for coarse fragments, outlined in the following section, are also added as adjectives to the soil class name and become a part of it. Thus a "gravelly sandy loam" has about 20 percent or more of gravel in the whole soil mass. The basic soil textural class name, however, is determined from the size distribution of the material below 2 mm. in diameter. That is, the percentages used for the standard soil class designations are net after the coarse fragments are excluded.

Phase names for stoniness and rockiness, although not a part of textural soil class names, are used to modify the soil-class part of a soil-type name, as for example, Gloucester *very stony* loam. In the descriptions of all soil horizons, particles larger than 10 inches are excluded from the soil textural class name. It needs to be recalled that classes of stoniness and rockiness are separate from soil class and have a separate place in soil descriptions.

Terms besides those herein defined, such as "wet," "ashy," "cindery," and the like, should be avoided in soil-class names or as modifiers of soil class in soil-type names.

[4] Tentative name for soils now included with Wiesenboden and for some included in Half Bog.

GENERAL GROUPING OF SOIL TEXTURAL CLASSES

The need for fine distinctions in the texture of soil horizons results in a large number of soil textural classes. Often it is convenient to speak generally of a broad group of textural classes. Although the terms "heavy" and "light" have been used for many years, they are confusing, since the terms arose from the power required in plowing, not the actual weight of the soil. According to local usage in a few places, "light" soils are those low in productivity, including especially ones of clay texture.

An outline of acceptable general terms, in three classes and in five, in relation to the basic soil textural class names, is shown as follows:

General terms:		*Basic soil textural class names*
Sandy soils.—*Coarse-textured soils*		Sands. Loamy sands.
Loamy soils.—	*Moderately coarse-textured soils*	Sandy loam. Fine sandy loam.
	Medium-textured soils	Very fine sandy loam. Loam. Silt loam. Silt.
	Moderately fine-textured soils	Clay loam. Sandy clay loam. Silty clay loam.
Clayey soils.—*Fine-textured soils*		Sandy clay. Silty clay. Clay.

COARSE FRAGMENTS

Significant proportions of fragments coarser than very coarse sand and less than 10 inches, if rounded, or 15 inches along the longer axis, if flat, are recognized by an appropriate adjective in the textural soil-class name. Such fragments are regarded as a part of the soil mass. They influence moisture storage, infiltration, and runoff. They influence root growth, especially through their dilution of the mass of active soil. They protect the fine particles from wash and blowing. They are moved with the soil mass in tillage.

Many names and standards have been proposed by geologists and soil scientists for these fragments. Fine distinctions are easily made (but not always easily mapped) because the fragments are easy to see; but finer distinctions than those set forth in table 3 have little or no real significance to soil genesis or behavior. Other variables, like the mineralogy of the clays or the nature of the organic matter, are far more important. The scientist must guard against making finer distinctions among the coarse fragments than those of real significance, simply because he can see them easily in the field.

The accepted adjectives to include in textural soil class names and the size limits of classes of coarse fragments are set forth in outline form in table 3. This table includes the probable maximum of detail required for detailed basic soil surveys. In situations where no useful purpose is served by developing separate mapping units to indicate the separate classes, the classes are grouped and a name given the soil type or soil phase that most clearly indicates the situation. Thus a cobbly loam or a stony phase may include other fragments also listed in the two right hand columns. In this section we shall concern ourselves only with fragments smaller than stones.

TABLE 3.—*Names used for coarse fragments in soils*[1]

Shape and kind of fragments	Size and name of fragments		
	Up to 3 inches in diameter	*3 to 10 inches in diameter*	*More than 10 inches in diameter*
Rounded and subrounded fragments (all kinds of rock).	Gravelly	Cobbly	Stony (or bouldery).[2]
Irregularly shaped angular fragments:			
Chert	Cherty	Coarse cherty.	Stony.
Other than chert	(Angular) gravelly.	Angular cobbly[3].	Do.
	Up to 6 inches in length	*6 to 15 inches in length*	*More than 15 inches in length*
Thin, flat fragments:			
Thin, flat sandstone, limestone, and schist.	Channery	Flaggy	Stony.
Slate	Slaty	do	Do.
Shale	Shaly	do	Do.

[1] The individual classes are not always differentiating characteristics of mapping units.
[2] Bouldery is sometimes used where stones are larger than 24 inches.
[3] Formerly called "stony."

The adjectives listed in the first two columns of table 3 are incorporated into the soil textural class designations of horizons when the soil mass contains significant proportions of the fragments, above 15 to 20 percent by volume, depending upon the other soil characteristics. These class names become parts of soil-type names. Where the coarse fragments make up 90 percent or more of the soil mass by volume in the upper 8 inches, the land is classified in the appropriate miscellaneous land type.[6] If necessary to make distinctions of clear significance, another subdivision can be made of the coarse fragments at about 50 percent to give, for example, gravelly loam (20 to 50 percent gravel) and very gravelly loam (50 to 90 percent gravel). The other defined fragments may be handled similarly.

The recommended terms to apply to soil containing above 15 to 20 percent coarse fragments smaller than stones, and less than 90 percent, are defined as follows:

Channery: Soils contain fragments of thin, flat sandstone, limestone, or schist up to 6 inches along the longer axis. A single piece is a *fragment*.

Cherty: Soils have angular fragments that are less than 3 inches in diameter, more than 75 percent of which are chert; *coarse cherty* soils have fragments of 3 to 10 inches (fig. 39). Unless the size distinction is significant to the use capability of the soil, the *cherty* soil includes the whole range up to 10 inches. Most cherty soils are developed from weathered cherty limestone. A single piece is a *chert fragment*.

Cobbly: Soils have rounded or partially rounded fragments of rock ranging from 3 to 10 inches in diameter. *Angular cobbly*, formerly included as stony, is similar to cobbly except that fragments are not rounded. A single piece of either is a *cobblestone* or *small stone*.

Flaggy: Soils contain relatively thin fragments 6 to 15 inches long of sandstone, limestone, slate, or shale, or, rarely, of schist. A single piece is a *flagstone*.

Gravelly: Soils have rounded or angular fragments, not prominently flattened, up to 3 inches in diameter. If 75 percent or more of the fragments is chert, the soils are called *cherty*. In descriptions, soils with pebbles mostly over 2 inches in diameter may be called *coarsely gravelly* soils, and those with pebbles mostly under one-half inch in diameter may be called *finely gravelly* soils. An individual piece is a *pebble*. The term "gravel" refers to a mass of pebbles.

Shaly: Soils have flattened fragments of shale less than 6 inches along the longer axis. A single piece is a *shale fragment*.

Slaty: Soils contain fragments of slate less than 6 inches along the longer axis. A single piece is a *slate fragment*.

Stony: Soils contain rock fragments larger than 10 inches in diameter, if rounded, and longer than 15 inches along the longer axis, if flat. Classes are outlined in the following section.

[6] Formerly, some soils having a high proportion of gravel or pebbles in the surface 8 inches were given a textural class name of "gravel," as in Rodman gravel. It is recommended that such soils be classified as gravelly loam, gravelly sandy loam, or gravelly sand, if they have less than 90 percent pebbles, or with the appropriate miscellaneous land type if they have more.

STONINESS AND ROCKINESS

Stones larger than 10 inches in diameter and rock outcrops are not regarded as part of the soil mass as defined by soil textural classes. They have an important bearing on soil use, however, because of their interference with the use of agricultural machinery and their dilution of the soil mass. In fact, stoniness, rockiness, or both, are the differentiating criteria between classes of arable soil and between arable and nonarable soil in many places. In large part the soils developed from glacial till, for example, especially where the till is thin, have characteristics that make them highly responsive to management, except for stoniness. Soil scientists have sometimes neglected this factor, perhaps in part because it is a difficult problem to deal with in the field. Several otherwise useful published soil surveys have failed in their objectives because of the failure to establish meaningful classes of stoniness. Although detailed attention was given soil color, texture, parent material, slope, erosion, depth, and the like, stoniness was so carelessly evaluated that the maps cannot be used to distinguish between potential cropland, pasture land, and forest land, in descending order of intensity.

The suggestions that follow differentiate between loose stones and fixed stones and provide classes within each as required in detailed basic surveys. Admittedly the suggestions are especially aimed to deal with the most complicated situations—where both loose stones and fixed stones exist and influence soil-use capability differently and where the soils are otherwise suitable for intensive use. Generally, loose stones are scattered over the soil area, while rock ledges are more concentrated in strips with relatively rock-free soil between. Such situations are most common in glaciated regions with thin drift, as in New England and parts of the northern Lake States.

Outside the glaciated regions, loose stones are less abundant, although by no means uncommon. In some sections of the country, soils containing fixed stones (rocky soils as here defined), some loose fragments 3 to 10 inches in diameter, and some stones have been called stony for many years. Where no useful purpose is served by dividing into additional types and phases, it should not be done. Thus the classes proposed for stoniness and rockiness may be grouped in the definition of any individual mapping unit.

STONINESS

Stoniness refers to the relative proportion of stones over 10 inches in diameter in or on the soil. The significance of a given number or amount of stones depends upon the other soil characteristics. That is, if a soil is not suited to cultivated crops anyway, the presence of enough stones to interfere with cultivation is not significant and should not be used as a basis for a soil phase separation. If a soil is exceedingly responsive to management for improved pasture, let us say, differences between even high degrees of stoniness are significant and may separate mapping units, as for example, an extremely stony phase of a soil type from the miscellaneous land type, Stony land.

The limits of the classes of stoniness are defined broadly in absolute terms and more specifically in terms of soil use wherever the other soil characteristics are favorable for crops or improved pasture. The able soil classifier avoids fine distinctions according to stoniness where they are not significant as clearly as he recognizes them where they are significant. This means that in the descriptive soil legend and in the soil survey report, stony phases need to be defined *within* the soil series and types. The classes of stoniness are used in definitions of all units of soil classification and may become one criterion for soil series as well as the sole criterion for distinctions among phases within the soil series or soil types.

Classes of stoniness are outlined as follows:

Class 0: No stones or too few to interfere with tillage. Stones cover less than 0.01 percent of the area.

Class 1: Sufficient stones to interfere with tillage but not to make intertilled crops impracticable. (If stones are 1 foot in diameter and about 30 to 100 feet apart, they occupy about 0.01 to 0.1 percent of the surface, and there are about 0.15 to 1.5 cubic yards per acre-foot.) (See fig. 40.)

Class 2: Sufficient stones to make tillage of intertilled crops impracticable, but the soil can be worked for hay crops or improved pasture if other soil characteristics are favorable. (If stones are 1 foot in diameter and about 5 to 30 feet apart, they occupy about 0.1 to 3 percent of the surface, and there are about 1.5 to 50 cubic yards per acre-foot.) (See fig. 41.)

Class 3: Sufficient stones to make all use of machinery impracticable, except for very light machinery or hand tools where other soil characteristics are especially favorable for improved pasture. Soils with this class of stoniness may have some use for wild pasture or forests, depending on other soil characteristics. (If stones are 1 foot in diameter and about 2.5 to 5 feet apart, they occupy about 3 to 15 percent of the surface, and there are about 50 to 240 cubic yards per acre-foot.)

Class 4: Sufficient stones to make all use of machinery impracticable; the land may have some value for poor pasture or for forestry. (If stones are 1 foot in diameter and are about 2.5 feet or less apart, they occupy 15 to 90 percent of the surface, and there are more than about 240 cubic yards per acre-foot.)

Class 5: Land essentially paved with stones that occupy more than 90 percent of the exposed surface (Rubble).

It should be emphasized that these classes are for general application in soil descriptions. They may or may not be used as phase distinctions. In other words a mapping unit may be defined in terms of more than one class of stoniness. Some individual soils may be defined in terms of classes of stoniness, classes of rockiness, and classes of coarse fragments. Stoniness is not a part of the soil textural class. The terms "stony," very stony," or "exceedingly stony" may modify the soil textural class name in the soil type; but this is simply a brief way of designating stony phases.[7] Soil series descriptions need to include the range of stoniness in terms of classes 0, 1, 2, and 3.

ROCKINESS

Rockiness refers to the relative proportion of bedrock exposures, either rock outcrops or patches of soil too thin over bedrock for use, in a soil area. "Rocky" is used, perhaps arbitrarily, for soils having fixed rock (bedrock), and "stony" for soils having loose detached fragments of rock.

The classes of rockiness, as of stoniness, are given broad definitions in absolute terms and more specific definitions in terms of soil use for those soils otherwise suitable for crops or improved pasture. Soil areas having the same definitions in terms of area of bedrock exposure may vary widely in the depth of soils between the rock outcrops. Such distinctions need to be made within the soil series definitions. As with stoniness, the classes of rockiness are used in soil series descriptions and can become one criterion for series distinctions or the sole criterion for phase distinctions. Two or more classes may be combined in one mapping unit. Some mapping units may also have classes of stoniness and of coarse fragments.

The relationships to soil use suggested in the definitions of the classes apply mainly to areas of soil in humid regions that are otherwise responsive to management. The definitions of actual soil phases must take account of the alternative management practices that can be used for seeding, harvesting, weed control, and the like.

In each descriptive legend and soil survey report, rocky phases need to be defined specifically within each soil series or type.

The classes of rockiness are as follows:

Class 0: No bedrock exposures or too few to interfere with tillage. Less than 2 percent bedrock exposed.

Class 1: Sufficient bedrock exposures to interfere with tillage but not to make intertilled crops impracticable. Depending upon how the pattern affects tillage, rock exposures are roughly 100 to 300 feet apart and cover about 2 to 10 percent of the surface.

Class 2: Sufficient bedrock exposures to make tillage of intertilled crops impracticable, but soil can be worked for hay crops or improved pasture if the other soil characteristics are favorable. Rock exposures are roughly 30 to 100 feet apart and cover about 10 to 25 percent of the surface, depending upon the pattern (fig. 42).

Class 3: Sufficient rock outcrop to make all use of machinery impracticable, except for light machinery where other soil characteristics are especially favorable for improved pasture. May have some use for wild pasture or forests, depending on the other soil characteristics. Rock exposures, or patches of soil too thin over rock for use, are roughly 10 to 30 feet apart and cover about 25 to 50 percent of the surface, depending upon the pattern.

Class 4: Sufficient rock outcrop (or of very thin soil over rock) to make all use of machinery impracticable. The land may have some value for poor pasture or for forestry. Rock outcrops are about 10 feet apart or less and cover some 50 to 90 percent of the area.

Class 5: Land for which over 90 percent of the surface is exposed bedrock (Rock outcrop).

SOIL STRUCTURE

Soil structure refers to the aggregation of primary soil particles into compound particles, or clusters of primary particles, which are separated from adjoining aggregates by surfaces of weakness. The exteriors of some aggregates have thin, often dark-colored, surface films which perhaps help to keep them apart. Other aggregates have surfaces and interiors of like color, and the forces holding the aggregates together appear to be wholly internal.

An individual natural soil aggregate is called a *ped*, in contrast to (1) a *clod*, caused by disturbance, such as plowing or digging, that molds the soil to a transient mass that slakes with repeated wetting and drying, (2) a *fragment* caused by rupture of the soil mass across natural surfaces of weakness, or (3) a *concretion* caused by local concentrations of compounds that irreversibly cement the soil grains together.

The importance of soil structure in soil classification and in influencing soil productivity can scarcely be overemphasized. The capability of any soil for the growth of plants and its response to management depends as much on its structure as on its fertility. Generally, in the United States, soils with aggregates of spheroidal shape have much pore space between aggregates, have more rapid permeability, and are more productive than soils of comparable fertility that are massive or even coarsely blocky or prismatic. In other parts of the world, some soils are overgranulated. Some Latosols have such well-developed spheroidal peds that the moisture-holding capacity is low, too few contacts exist between roots and soil, and the soils are relatively unproductive.

Field descriptions of soil structure note (1) the shape and arrangement, (2) the size, and (3) the distinctness and durability of the visible aggregates or peds. Field terminology for structure consists of separate sets of terms designating each of these three qualities, which by combination form the names for structure. Shape and arrangement of peds is designated as *type* of soil structure; size of peds, as *class;* and degree of distinctness, as *grades.*[1] The structural pattern of a soil horizon also includes the shapes and sizes of pore spaces as well as those of the peds themselves.

There are four primary types of structure: (1) Platy, with particles arranged around a plane, generally horizontal; (2) prismlike, with particles arranged around a vertical line and bounded by relatively flat vertical surfaces; (3) blocklike or polyhedral, with particles arranged around a point and bounded by flat or rounded surfaces which are casts of the molds formed by the faces of surrounding peds; and (4) spheroidal or polyhedral, with particles arranged around a point and bounded by curved or very irregular surfaces that are not accommodated to the adjoining aggregates. Each of the last three have two subtypes. Under prismlike the subtypes are *prismatic*, without rounded upper ends, and *columnar*, with rounded caps. The subtypes of blocklike are *angular blocky*, bounded by planes intersecting at relatively sharp angles, and *subangular blocky*, having mixed rounded and plane faces with vertices mostly rounded. If the term "blocky" is used alone, angular blocky is understood. Spheroidal is subdivided into *granular*, relatively nonporous, and *crumb*, very porous. Each type of structure includes peds that vary in shape, and detailed soil descriptions may require supplemental statements about the shape of the individual peds (figs. 43 and 44).

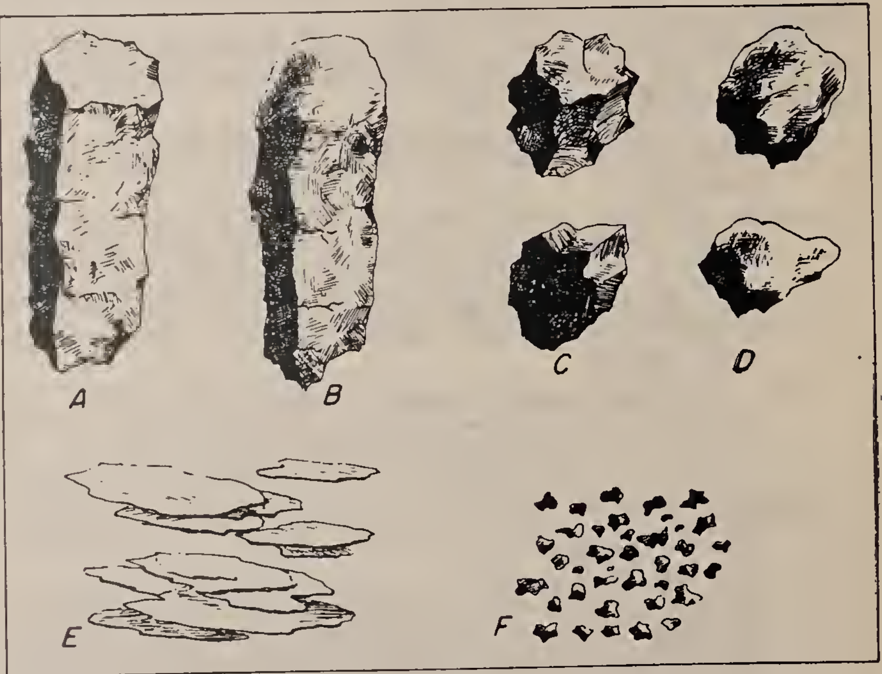

FIGURE 44.—Drawings illustrating some of the types of soil structure: *A*, prismatic; *B*, columnar; *C*, angular blocky; *D*, subangular blocky; *E*, platy; and F, granular.

The names in the preceding paragraph placed in italics are the terms most used in descriptions of soil horizons. *Nut* has been used for blocklike peds, but is not recommended; *nuciform* has been an optional alternative for subangular blocky, but *subangular blocky* is recommended. It is difficult for many to dissociate a size connotation from terms like *nut* and *nuciform*. For this reason some confuse very fine blocky with granular. Terms

[1] For a useful background discussion of these concepts, see NIKIFOROFF, C. C. MORPHOLOGICAL CLASSIFICATION OF SOIL STRUCTURE. Soil Sci. 52: 193–212, illus. 1941.

TABLE 6.—*Types and classes of soil structure*

Class	TYPE (Shape and arrangement of peds)						
	Platelike with one dimension (the vertical) limited and greatly less than the other two; arranged around a horizontal plane; faces mostly horizontal.	Prismlike with two dimensions (the horizontal) limited and considerably less than the vertical; arranged around a vertical line; vertical faces well defined; vertices angular.		Blocklike; polyhedronlike, or spheroidal, with three dimensions of the same order of magnitude, arranged around a point.			
				Blocklike; blocks or polyhedrons having plane or curved surfaces that are casts of the molds formed by the faces of the surrounding peds.		Spheroids or polyhedrons having plane or curved surfaces which have slight or no accommodation to the faces of surrounding peds.	
		Without rounded caps.	With rounded caps.	Faces flattened; most vertices sharply angular.	Mixed rounded and flattened faces with many rounded vertices.	Relatively nonporous peds.	Porous peds.
	Platy	Prismatic	Columnar	(Angular) Blocky [1]	Subangular blocky [2]	Granular	Crumb
Very fine or very thin.	Very thin platy; <1 mm.	Very fine prismatic; <10 mm.	Very fine columnar; <10 mm.	Very fine angular blocky; <5 mm.	Very fine subangular blocky; <5 mm.	Very fine granular; <1 mm.	Very fine crumb; <1 mm.
Fine or thin	Thin platy; 1 to 2 mm.	Fine prismatic; 10 to 20 mm.	Fine columnar; 10 to 20 mm.	Fine angular blocky; 5 to 10 mm.	Fine subangular blocky; 5 to 10 mm.	Fine granular; 1 to 2 mm.	Fine crumb; 1 to 2 mm.
Medium	Medium platy; 2 to 5 mm.	Medium prismatic; 20 to 50 mm.	Medium columnar; 20 to 50 mm.	Medium angular blocky; 10 to 20 mm.	Medium subangular blocky; 10 to 20 mm.	Medium granular; 2 to 5 mm.	Medium crumb; 2 to 5 mm.
Coarse or thick.	Thick platy; 5 to 10 mm.	Coarse prismatic; 50 to 100 mm.	Coarse columnar; 50 to 100 mm.	Coarse angular blocky; 20 to 50 mm.	Coarse subangular blocky; 20 to 50 mm.	Coarse granular; 5 to 10 mm.	
Very coarse or very thick.	Very thick platy; >10 mm.	Very coarse prismatic; >100 mm.	Very coarse columnar; >100 mm.	Very coarse angular blocky; >50 mm.	Very coarse subangular blocky; >50 mm.	Very coarse granular; >10 mm.	

[1] (a) Sometimes called *nut*. (b) The word "angular" in the name can ordinarily be omitted.
[2] Sometimes called *nuciform, nut,* or *subangular nut*. Since the size connotation of these terms is a source of great confusion to many, they are not recommended.

used to designate types of soil structure refer *only* to shape and arrangement and do not specify size.

Five size classes are recognized in each of the primary types. The names of these and their size limits, which vary with the four primary types for shape and arrangement, are given in table 6.

Grade of structure is the degree of aggregation and expresses the differential between cohesion within aggregates and adhesion between aggregates. In field practice, grade of structure is determined mainly by noting the durability of the aggregates and the proportions between aggregated and unaggregated material that result when the aggregates are displaced or gently crushed. Grade of structure varies with the moistening of the soil and should be described at the most important moisture contents of the soil horizon. The principal description of the structure of a soil horizon should refer to its normal moisture content, although attention should be called to any striking contrasts in structure under other moisture conditions to which the soil is subject. If grade is designated at an unstated moisture content, it is assumed that the soil is nearly dry or only very slightly moist, which is commonly that part of the range in soil moisture in which soil structure is most strongly expressed.

With exposure, structure may become much altered, often much stronger. Old road cuts are not suitable places to determine the grade of structure, but they often afford a clue to the type of structure present where the grade is so weak that it cannot be identified in the undisturbed soil.

Terms for grade of structure are as follows:

0. *Structureless.*—That condition in which there is no observable aggregation or no definite orderly arrangement of natural lines of weakness. *Massive* if coherent; *single grain* if noncoherent.
1. *Weak.*—That degree of aggregation characterized by poorly formed indistinct peds that are barely observable in place. When disturbed, soil material that has this grade of structure breaks into a mixture of few entire peds, many broken peds, and much unaggregated material. If necessary for comparison, this grade may be subdivided into *very weak* and *moderately weak.*
2. *Moderate.*—That grade of structure characterized by well-formed distinct peds that are moderately durable and evident but not distinct in undisturbed soil. Soil material of this grade, when disturbed, breaks down into a mixture of many distinct entire peds, some broken peds, and little unaggregated material. Examples are the loam A horizons of typical Chestnut soils in the granular type, and clayey B horizons of such Red-Yellow Podzolic soils as the Boswell in the blocky type.
3. *Strong.*—That grade of structure characterized by durable peds that are quite evident in undisplaced soil, that adhere weakly to one another, and that withstand displacement and become separated when the soil is disturbed. When removed from the profile, soil material of this grade of structure consists very largely of entire peds and includes few broken peds and little or no unaggregated material. If necessary for comparison, this grade may be subdivided into *moderately strong* and *very strong.* Examples of strong grade of structure are in the granular-type A horizons of the typical Chernozem and in the columnar-type B horizons of the typical solodized-Solonetz.

The sequence followed in combining the three terms to form the compound name of the structure is (1) grade (distinctness), (2) class (size), and (3) type (shape). For example, the designation for the soil structure in which the peds are loosely packed and roundish but not extremely porous, dominantly between 1 and 2 mm. in diameter, and quite distinct is *strong fine granular.* The designation of structure by grade, class, and type can be modified with any other appropriate terms wherever necessary to describe other characteristics of the peds.

Many soil horizons have compound structure consisting of one or more sets of smaller peds held together as larger peds. Compound structures are so described: for example, *compound moderate very coarse prismatic and moderate medium granular.* Soil that has one structural form when in place may assume some other form when disturbed. When removed, the larger peds may fall into smaller peds, such as large prisms into medium blocks.

With increasing disturbance or pressure any aggregate breaks into smaller particles. These finer particles may or may not be peds, depending on whether their form and size are determined by surfaces of weakness between natural aggregates or by the place and direction of the pressures applied. Mere breakage into fragments larger than the soil grains without some orderly shape and size should not be confused with soil structure. Massive soil horizons, without structure, can be shattered into fragments—so can glass. Such fragments are not peds.

SOIL CONSISTENCE

Soil consistence comprises the attributes of soil material that are expressed by the degree and kind of cohesion and adhesion or by the resistance to deformation or rupture. Every soil material has consistence irrespective of whether the mass be large or small, in a natural condition or greatly disturbed, aggregated or structureless, moist or dry. Although consistence and structure are interrelated, structure deals with the shape, size, and definition of natural aggregates that result from variations in the forces of attraction within a soil mass, whereas consistence deals with the strength and nature of such forces themselves.

The terminology for consistence includes separate terms for description at three standard moisture contents (dry, moist, and wet). If moisture conditions are not stated in using any consistence term, the moisture condition is that under which the particular term is defined. Thus *friable* used without statement of the moisture content specifies *friable when moist;* likewise, *hard* used alone means *hard when dry,* and *plastic* means *plastic when wet.* If a term is used to describe consistence at some moisture content *other* than the standard condition under which the term is defined, *a statement of the moisture condition is essential.* Usually it is unnecessary to describe consistence at all three standard moisture conditions. The consistence when moist is commonly the most significant, and a soil description with this omitted can hardly be regarded as complete; the consistence when dry is generally useful but may be irrelevant in descriptions of soil materials that are never dry; and the consistence when wet is unessential in the description of many soils but extremely important in some.

Although evaluation of consistence involves some disturbance, unless otherwise stated, descriptions of consistence customarily refer to that of soil from undisturbed horizons. In addition, descriptions of consistence under moist or wet conditions carry an implication that disturbance causes little modification of consistence or that the original consistence can be almost restored by pressing the material together. Where such an implication is misleading, as in compacted layers, the consistence both before and after disturbance may require separate description. Then, too, compound consistences occur, as in a loose mass of hard granules. In a detailed description of soils having compound structure, the consistence of the mass as a whole and of its parts should be stated.

A number of terms, including *brittle, crumbly, dense, elastic, fluffy,*[1] *mealy, mellow, soft, spongy, stiff, tight, tough,* and some others, which have often been used in descriptions of consistence, are not here defined. These are all common words of well-known meanings. Some are indispensable for describing unusual conditions not covered by other terms. They are useful in nontechnical descriptions where a little accuracy may be sacrificed to use a term familiar to lay readers. Whenever needed, these or other terms for consistence not defined in this *Manual* should be employed with meanings as given in standard dictionaries.

[1] As used in describing soils, *fluffy* denotes a combination of loose to very friable consistence and low bulk density.

The terms used in soil descriptions for consistence follow:

I. CONSISTENCE WHEN WET

Consistence when wet is determined at or slightly above field capacity.

A. **Stickiness.**—Stickiness is the quality of adhesion to other objects. For field evaluation of stickiness, soil material is pressed between thumb and finger and its adherence noted. Degrees of stickiness are described as follows:

0. *Nonsticky:* After release of pressure, practically no soil material adheres to thumb or finger.
1. *Slightly sticky:* After pressure, soil material adheres to both thumb and finger but comes off one or the other rather cleanly. It is not appreciably stretched when the digits are separated.
2. *Sticky:* After pressure, soil material adheres to both thumb and finger and tends to stretch somewhat and pull apart rather than pulling free from either digit.
3. *Very sticky:* After pressure, soil material adheres strongly to both thumb and forefinger and is decidedly stretched when they are separated.

B. **Plasticity.**—Plasticity is the ability to change shape continuously under the influence of an applied stress and to retain the impressed shape on removal of the stress. For field determination of plasticity, roll the soil material between thumb and finger and observe whether or not a wire or thin rod of soil can be formed. If helpful to the reader of particular descriptions, state the range of moisture content within which plasticity continues, as, plastic when slightly moist or wetter, plastic when moderately moist or wetter, and plastic only when wet, or as plastic within a wide, medium, or narrow range of moisture content. Express degree of resistance to deformation at or slightly above field capacity as follows:

0. *Nonplastic:* No wire is formable.
1. *Slightly plastic:* Wire formable but soil mass easily deformable.
2. *Plastic:* Wire formable and moderate pressure required for deformation of the soil mass.
3. *Very plastic:* Wire formable and much pressure required for deformation of the soil mass.

II. CONSISTENCE WHEN MOIST

Consistence when moist is determined at a moisture content approximately midway between air-dry and field capacity. At this moisture content most soil materials exhibit a form of consistence characterized by (a) tendency to break into smaller masses rather than into powder, (b) some deformation prior to rupture, (c) absence of brittleness, and (d) ability of the material after disturbance to cohere again when pressed together. The resistance decreases with moisture content, and accuracy of field descriptions of this consistence is limited by the accuracy of estimating moisture content. To evaluate this consistence, select and attempt to crush in the hand a mass that appears slightly moist.

0. *Loose:* Noncoherent.
1. *Very friable:* Soil material crushes under very gentle pressure but coheres when pressed together.
2. *Friable:* Soil material crushes easily under gentle to moderate pressure between thumb and forefinger, and coheres when pressed together.
3. *Firm:* Soil material crushes under moderate pressure between thumb and forefinger but resistance is distinctly noticeable.
4. *Very firm:* Soil material crushes under strong pressure; barely crushable between thumb and forefinger.
5. *Extremely firm:* Soil material crushes only under very strong pressure; cannot be crushed between thumb and forefinger and must be broken apart bit by bit.

The term *compact* denotes a combination of firm consistence and close packing or arrangement of particles and should be used only in this sense. It can be given degrees by use of "very" and "extremely."

III. CONSISTENCE WHEN DRY

The consistence of soil materials when dry is characterized by rigidity, brittleness, maximum resistance to pressure, more or less tendency to crush to a powder or to fragments with rather sharp edges, and inability of crushed material to cohere again when pressed together. To evaluate, select an air-dry mass and break in the hand.

0. *Loose:* Noncoherent.
1. *Soft:* Soil mass is very weakly coherent and fragile; breaks to powder or individual grains under very slight pressure.
2. *Slightly hard:* Weakly resistant to pressure; easily broken between thumb and forefinger.
3. *Hard:* Moderately resistant to pressure; can be broken in the hands without difficulty but is barely breakable between thumb and forefinger.
4. *Very hard:* Very resistant to pressure; can be broken in the hands only with difficulty; not breakable between thumb and forefinger.
5. *Extremely hard:* Extremely resistant to pressure; cannot be broken in the hands.

IV. CEMENTATION

Cementation of soil material refers to a brittle hard consistence caused by some cementing substance other than clay minerals, such as calcium carbonate, silica, or oxides or salts of iron and aluminum. Typically the cementation is altered little if any by moistening; the hardness and brittleness persist in the wet condition. Semireversible cements, which generally resist moistening but soften under prolonged wetting, occur in some soils and give rise to soil layers having a cementation that is pronounced when dry but very weak when wet. Some layers cemented with calcium carbonate soften somewhat with wetting. Unless stated to the contrary, descriptions of cementation imply that the condition is altered little if any by wetting. If the cementation is greatly altered by moistening, it should be so stated. Cementation may be either continuous or discontinuous within a given horizon.

1. *Weakly cemented:* Cemented mass is brittle and hard but can be broken in the hands.
2. *Strongly cemented:* Cemented mass is brittle and harder than can be broken in the hand but is easily broken with a hammer.
3. *Indurated:* Very strongly cemented; brittle, does not soften under prolonged wetting, and is so extremely hard that for breakage a sharp blow with a hammer is required; hammer generally rings as a result of the blow.

NOMENCLATURE OF SOIL HORIZONS

U.S. Department of Agriculture Classification System (1938)

Horizon designations as set forth in the 1951 Soil Survey Manual, Agricultural Handbook No. 18, U.S.D.A..

Aoo - A surface horizon consisting of relatively fresh leaves, twigs and other plant remains, generally of the past year.

Ao - A surface horizon below the Aoo, if present, and above the A1; it consists of partly decomposed or matted plant remains. The Aoo and the Ao are measured upward from the top of the A1, if present, otherwise from the upper mineral soil horizon.

A1 - The surface mineral soil horizon relatively high in organic matter. It may or may not be a horizon of eluviation, It is usually dark in color.

A2 - This horizon is usually lighter in color than the underlying horizon, it has lost clay minerals, iron or aluminum or all three. A horizon of eluviation (the leaching of materials out in solution and suspension).

A3 - A horizon transitional to the B but more like the A than B. If the transitional horizon is not clearly divided it may be designated as the AB horizon.

Ap - A plowed or otherwise mixed surface horizon. The letter p indicates disturbance. Where the plow layer is entirely within the A1 horizon, it is designated as A1p.

B1 - Transitional to the A horizon above but more like the B than A.

B2 - The subhorizon of (1) maximum accumulation of silicate clay minerals or of iron and organic material; or (2) maximum development of blocky or prismatic structure, or characteristics of both.

B3 - Transitional to the C horizon but more like the B than the C.

C - A layer of unconsolidated material, relatively little affected by the influence of organisms and presumed to be similar in chemical, physical and mineralogical composition to the material from which at least a portion of the overlying solum has developed.

D - Any stratum underlying the C, or the B if no C is present, which is unlike the C or unlike the material from which the solum has been formed.

Lower case letters are used as suffixes to indicate selected subordinate departures from the assumed parent material or to indicate selected specific kinds of major departures from the definition.

b - The designation of a buried genetic horizon or horizons. Horizons of another solum may or may not have formed in the overlying material, which may be similar to or different from, the assumed parent material of the buried soil.

ca - An accumulation of carbonates, commonly calcium carbonate.

cs - An accumulation of calcium sulfate.

cn - An accumulation of concretions rich in iron, iron and manganese, or iron and phosphate.

f - Soil that is frozen at the time the soil is described. It may or may not be permanently frozen.

g - A gleyed horizon, the intense reduction of iron during soil development, or reducing conditions due to stagnant water.

h - Accumulations of decomposed illuvial organic matter, appearing as dark coating on sand or silt particles.

ir - Accumulations of illuvial iron as coatings on sand or silt particles.

m - Indurated horizons composed mainly of silicate minerals.

p - Indicates disturbance by cultivation or pasturing, especially of the A horizon.

r - A layer of hard rock, in the D horizon.

sa - An accumulation of soluble salts other than calcium carbonate or calcium sulfate.

t - An accumulation of translocated silicate clay, as in the B2 horizon.

u - An unconformable layer with inherited characteristics unlike those of the adjacent soil material, such as a stone line within a B horizon making it B3u.

Soil Classification (7th Approximation) 1960

Organic Horizons

0 - Organic horizons of mineral soils. Horizons: (1) formed or forming in the upper part of mineral soils and above the mineral part; (2) dominated by fresh or partly decomposed organic material; (3) containing more than 30 percent organic matter if the mineral fraction is more than 50 percent clay, or more than 20 percent organic matter if the mineral fraction has no clay. Intermediate clay content requires proportional organic-matter content.

01 -- Organic horizons in which essentially the original form of most vegetative matter is visible to the naked eye.

02 - Organic horizons in which the original form of most plant or animal matter cannot be recognized with the naked eye.

Mineral Horizons

A - Mineral horizons consisting of: (1) horizons of organic-matter accumulation formed or forming at, or adjacent to the surface; (2) horizons that have lost clay, iron or aluminum with resultant concentration of quartz or other resistant minerals of sand or silt size; (3) horizons dominated by 1 or 2 above but transitional to an underlying B or C.

A1 - Mineral horizons, formed or forming at or adjacent to the surface in which the feature emphasized is an accumulation of humified organic matter intimately associated with the mineral fraction. Mineral particles have coatings of organic material. The horizon is as dark as, or darker than the underlying horizons.

A2 - Mineral horizons in which the feature emphasized is loss of clay, iron or aluminum, with resultant concentration of quartz or other resistant minerals in sand and silt sizes. Commonly such horizons are lighter colored and have coarser textures than the underlying B, but not always. The A2 may also have a lighter color and be generally lower in organic content than the overlying A1.

A3 - A transitional horizon between A and B, and dominated by properties characteristic of an overlying A1 or A2 but having some subordinate properties of an underlying B.

AB - A horizon transitional between A and B. The upper part of the horizon is dominated by properties of the A and the lower part by B. The parts cannot be conveniently separated into A3 and B1. The combined horizon is normally thin.

A & B - Horizons that would qualify for A2 except for included parts constituting less than 50 percent of the volume that would qualify as B. This horizon is commonly predominantly A2 material partially surrounding thin, columnar-like upward extensions of the B.

AC - Transitional horizon between A and C, with subordinate properties of both A and C, but not dominated by either.

B - A horizon in which the dominant feature or features are one or more of the following: (1) illuvial concentration of silicate clay, iron, aluminum or humus, alone or in combination; (2) residual concentration of sesquioxides or silicate clays; (3) coatings of sesquioxides thick enough to give a darker, stronger or redder color than the over or underlying horizons; (4) alteration of material from its original condition.

B1 - A transitional horizon between the B and A1 or between B and A2 in which the horizon is dominated by properties of an underlying B2 but has some subordinate properties of an overlying A1 or B2.

B & A - Any horizon qualifying as B in more than 50 percent of its volume including parts that qualify as A2. These horizons commonly have vertical tongues of A2 material extending downward into the B from the A2. Cracks and earthworm channels filled with A2 or A2 material should be described and not designated as B and A.

B2 - A horizon transitional to an adjacent overlying A or an adjacent underlying C or R.

B3 - A transitional horizon between B and C or R in which the properties diagnostic of an overlying B2 are clearly expressed but are associated with clearly expressed properties characteristic of C or R. The B3 designation is used only if there is a B2 horizon.

C - A mineral horizon, excluding bedrock that is either like or unlike the material from which the solum is presumed to have formed. The C lacks properties diagnostic of A or B but includes materials modified by: (1) weathering outside the zone of major biological activity; (2) development of brittleness, high bulk density, and reversible comentation; (3) gleying (characterized by the presence of ferrous iron and neutral gray colors); (4) accumulation of calcium or magnesium carbonate or more soluble salts; (5) cementation by accumulations of calcium or magnesium carbonate or more soluble salts; (6) cementation by alkali - soluble siliceous material or by iron and silica.

R - Underlying consolidated bedrock, such as sandstone, limestone or granite. If the consolidated bedrock is presumed to be like the parent rock from which the adjacent overlying layer or horizon was formed, the symbol R is used alone. If presumed to be unlike the overlying material, the R is preceded by a Roman numeral denoting lithologic discontinuity.

Symbols used to indicate departures subordinate to those indicated by capitol letters.

b - Symbol added to the designation of a buried genetic horizon or horizons.

ca - Accumulation of carbonates of alkaline earths, commonly calcium. Applied to A, B or C horizons. The horizon must have more carbonates than the parent material is presumed to have had.

cs - An accumulation of calcium sulfate, commonly occurring in the C below ca accumulations but it may occur in other horizons as well. There must be more sulfates than the parent material is presumed to have had before the symbol cs can be used.

cn - Accumulations of concretions or hard nonconcretionary nodules enriched in sesquioxides with or without phorphorus.

f - Frozen soil, they may or may not be permanently frozen.

g - A horizon designation to indicate strong gleying (intense reduction of iron during soil development, or reducing conditions due to stagnant water). Base colors approach neutral, with or without mottles. The symbol g may be used with any of the major symbols for mineral horizons, A, B and C.

h - Accumulations of decomposed illuvial organic matter, appearing as dark coatings on sand or silt particles, or as discrete dark pellets of silt size. This suffix is used with the B horizon designation, as B_h or $B2_h$.

ir - Illuvial iron as coatings on sand or silt particles or as pellets of silt size. In some horizons the accumulations have filled pores, and cemented the horizons.

m - Indicates irreversible cementation such as found in a duripan. The symbol m does not apply to indurated (very strong cementation, hammer required to break) bedrock. The symbol m is not used to indicate firmness, as in fragipans.

p - A suffix used to indicate a disturbance by cultivation or pasturing. Even when the A horizon has been eroded away and the plowing is in what was the B horizon the designation A_p is used.

sa - Designation applied to any horizon where there is an accumulation of salts more soluble than calcium sulfate. When the sa symbol is used the horizon must have more salt than the parent material is presumed to have had.

si - The cementation by siliceous material, soluble in alkali. The symbol applies only to the C horizon. If the cementation is continuous and not nodular sim is used.

t - The suffix t is used to indicate accumulations of translocated silicate clays in the B horizon.

x - Designation to indicate genetically developed properties of brittleness, firmness, high density and other characteristics that are diagnostic of fragipans.

Lithologic Discontinuities

When it is necessary to number a series of contrasting material consecutively from the surface down, Roman numerals are prefixed to the horizon designations. A soil of one kind of material would be prefixed by the numeral I, therfore this numeral is omitted, as it is understood that all the material is I. Numbering starts with the second contrasting layer which is designated as II and each layer below is numbered consecutively. When a layer below a layer designated as II is similar to the topmost layer it is given the appropriate consecutive number in the sequence.

Unified Soil Classification System

Coarse-Grained Soils (More than half of material is larger than No. 200 sieve size)								Fine-Grained Soils (More than half of material is smaller than No. 200 sieve size)						
Gravels (More than half of coarse fraction is larger than No. 4 sieve size)				Sands (More than half of coarse fraction is smaller than No. 4 sieve size)				Silts & Clays (Liquid limit less than 50)			Silts & Clays (Liquid limit greater than 50)			Highly Organic Soil
Clean gravels (Little or no fines)		Gravels with fines (appreciable amount of fines)		Clean sands (Little or no fines)		Sands with fines (Appreciable amount of fines)								
GW	GP	GM	GC	SW	SP	SM	SC	ML	CL	OL	MH	CH	OH	Pt
Well graded gravels, gravel - sand mixture, little or no fines	Poorly graded gravels, gravel - sand mixtures, little or no fines	Silty gravels, gravel - sand - silt mixtures	Clayey gravels, gravel - sand - clay mixtures	Well graded sands, gravelly sands, little or no fines	Poorly graded sands, gravelly sands, little or no fines	Silty sands, sand-silt mixtures	Clayey sands, sand-silt mixtures	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Organic silts and organic silty clays of low pasticity	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Inorganic clays of high plasticity, fat clays	Organic clays of medium to high plasticity, organic silts	Peat and other highly organic soils

SOIL REACTION

Soil reaction is the degree of acidity or alkalinity of a soil mass, expressed in either pH or in words, as follows:

			pH
Extremely acid	below		4.5
Very strongly acid	4.5	-	5.0
Strongly acid	5.1	-	5.5
Medium acid	5.6	-	6.0
Slightly acid	6.1	-	6.5
Neutral	6.6	-	7.3
Mildly alkaline	7.4	-	7.8
Moderately alkaline	7.9	-	8.4
Strongly alkaline	8.5	-	9.0
Very strongly alkaline	9.1	and	higher

A pH value above 7 usually indicates the presence of some free carbonates of calcium, magnesium, or both, but not always. Some of the Solonetz soils of pH 8.5 show no test for carbonates in the field. Soils having a pH higher than 8.5 nearly always contain significant amounts of exchangeable sodium. Even some soils having a pH below 8.5 have large amounts of exchangeable sodium if they are low in exchangeable calcium.

Soil pH is determined either by the electrometric or colormetric method. The colormetric method using indicator dyes is the principal means of determining pH in the field.

PERCENT SOIL SEPARATES IN TEXTURAL CLASSES 1/

Textural Class 2/	Sand %	Silt %	Clay %
Loam	23-52	28-50	7-27
Silt loam	50 or less	50-88	27 or less
Silt	20 or less	80 or more	12 or less
Sandy clay loam	45-80	28 or less	20-35
Clay loam	20-45	15-53	27-40
Silty clay loam	20 or less	40-72	27-40
Sandy clay	45-65	20 or less	35-55
Silty clay	20 or less	40-60	40-60
Clay	45 or less	40 or less	40 or more

1/ Chart does not include Sands, Loamy sands or Sandy loams

2/ These definitions are not entirely adequate for unusual mixtures near the boundaries between classes. Some classes are not mutually exclusive.

FIELD DETERMINATION OF SOIL TEXTURAL CLASS

(by C. F. Shaw)

Sand: Sand is loose and single-grained. The individual grains can readily be seen or felt. Squeezed in the hand when dry it will fall apart when the pressure is released. Squeezed in the hand when moist, it will form a cast but will crumble when touched.

Sandy loam: A sandy loam is a soil containing much sand but which has enough silt and clay to make it somewhat coherent. The individual sand grains can readily be seen and felt. Squeezed when dry, it will form a cast which will readily fall apart, but if squeezed when moist a cast can be formed that will bear careful handling without breaking.

Loam: A loam is a soil having a relatively even mixture of different grades of sand and of silt and clay. It is mellow with a somewhat gritty feel, yet fairly smooth and slightly plastic. Squeezed when dry, it will form a cast that will bear careful handling, while the cast formed by squeezing the moist soil can be handled quite freely without breaking.

Silt loam: A silt loam is a soil having a moderate amount of fine grades of sand and only a small amount of clay, over half of the particles being of the size called "silt". When dry it may appear cloddy but the lumps can be readily broken, and when pulverized it feels soft and floury. When wet the soil readily runs together and puddles. Either dry or moist it will form casts that can be freely handled without breaking, but when moistened and squeezed between thumb and finger it will not "ribbon" but will give a broken appearance.

Clay loam: A clay loam is a fine textured soil which usually breaks into clods or lumps that are hard when dry. When the moist soil is pinched between the thumb and finger it will form a thin "ribbon" which will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into a heavy compact mass.

Clay: A clay is a fine textured soil that usually forms very hard lumps or clods when dry and is quite plastic and usually sticky when wet. When the moist soil is pinched out between the thumb and fingers it will form a long, flexible "ribbon". Some fine clays very high in colloids are friable and lack plasticity in all conditions of moisture.

Based on Information from
U. S. Department of Agriculture
Soil Conservation Service
(Rev.) February, 1962

LEGEND FOR RANGE SITES - MONTANA

Range sites are kinds of range land that differ from each other in their ability to produce a significantly different kind or amount of original vegetation. Current vegetative cover is indicated by the Range Condition Class. Only natural grasslands can be classified as range sites. A soil group name is combined with the precipitation belt to designate a specific range site; e.g. Sandy 10-14". The following range sites are listed in presumed order of natural productivity in "Excellent" condition.

Range Site Descriptions:

WL -WET LAND: Marshy lands with subirrigation where seepage, ponding, etc. raises water table to above the surface during only a part of the growing season. Too wet for cultivated crops but too dry for common reed, cattails, or true aquatics.

Sb -SUBIRRIGATED: Lands with water table rarely above the surface during the growing season but subirrigated most of the growing season.

SS -SALINE SUBIRRIGATED: Subirrigated land where salt and/or alkali accumulations are apparent and halophytes occur over a major part of the area.

Ov -OVERFLOW: Areas regularly receiving more than normal soil moisture because of run-in from higher land, including stream overflow, run-in from higher slopes, and areas with water spreading systems.

SO -SALINE OVERFLOW: Areas regularly receiving more than normal soil moisture because of run-in, where salt and/or alkali accumulations are apparent and halophytes occur over a major part of the area.

Sa -SANDS: Deep, loose, fine sands and very fine sands on nearly level to rolling relief; excepting compact dark nearly level loamy fine sands and loamy very fine sands.

Sv -SAVANNAH: Uplands on which grass cover with isolated trees is normal (climax). Do not confound with savannah type of cover resulting from overgrazing of natural grassland or cutting of natural forest land. This site is common at margins of forest climates and in grassland climates where soil moisture relations especially favor tree growth.

Sy -SANDY: All normal coarse to fine sandy loams (not true sands) plus dark nearly level loamy fine sands, and loamy very fine sands; excepting relatively impervious cemented sands.

Si -SILTY: All normal very fine sandy loams, loams, silt loams, and silts.

Cy -CLAYEY: All normal relatively pervious sandy to silty clay loams and clays--normally granular.

TSy-THIN SANDY: Thin but deep sandy soils--not true sands--usually of hills with smooth surfaced slopes generally over 20% but also of lesser slopes where cementing occurs in upper layers on drying.

TSi-THIN SILTY: Thin but deep silty soils of hills with smooth surfaced slopes generally over 15%.

TCy-THIN CLAYEY: Thin but deep clayey soils of hills with smooth surfaced slopes generally over 15%.

SwC-SHALLOW CLAY: Shallow normally granular clays of hills (10-20") often underlain by angular raw shale fragments.

SwG-SHALLOW TO GRAVEL: Shallow soils (10-20") resting on clean gravelly gravelly or cobbly materials.

SwL-SHALLOW LIMY: Shallow limy soils (10-20") underlain by rock virtually impenetrable by plant roots.

SwN-SHALLOW NONLIMY: Shallow neutral to acid soils (10-20") underlain by rock virtually impenetrable by roots.

Ps -PANSPOTS: Areas where hard clays or other impervious materials lie close to or at the surface in shallow depressions which occupy 20 to 50% of the area.

DC -DENSE CLAY: Relatively impervious deep but dispersed clays-may be overlain by thin but ineffectual layers of other materials. The dispersed layer is very hard to extremely hard when dry and very sticky when wet.

TB -THIN BREAKS: Mixed soils of various depths derived from different parent materials that outcrop at different levels forming irregular slopes of from 20 to 65 percent. Trees may occur locally above outcrops.

Gr -GRAVEL: Uplands where rock fragments of gravel or small stone size compose most of the soil with coarse materials greatly reducing moisture retention with apparent effects on both amount and kind of native vegetation.

VS -VERY SHALLOW: Areas where few roots can penetrate deeper than 10". Outcropping of gravel or bedrock is characteristic. Joints in bedrock may develop deep soil pockets usually marked by tall grasses, shrubs, or stunted trees.

SU -<u>SALINE UPLAND</u>: Uplands of ordinary depth where salt and/or alkali accumulations are apparent and halophytes occur over a major part of the area.

Sh -<u>SHALE</u>: Readily puddled uplands where some unweathered angular raw shale fragments are exposed at the surface and little, if any, soil profile development is evident.

BL -<u>BADLANDS</u>: Nearly barren lands broken by drainages dry most of the year, with intermingled grazable areas too small or too narrow to justify mapping separately.

Descriptive Legend Example

The descriptive soil legend as explained in the report is the most important tool of the soil survey. Using this tool the soil scientist can plot the boundaries of mapping units. The quality of the descriptive legend will be reflected in the degree of accuracy and quality of the field mapping. Writing a good descriptive legend is challenging and difficult. Part of a descriptive legend is found below. This is an example showing what the series description and mapping unit descriptions contain. These two sections of the legend are probably the most important, other sections of the legend are not shown. An explanation of terms used in the profile description can be found in the section of the report on "Soil Profile Descriptions".

Series Description

HYDRO SERIES

The Hydro series consists of strongly solodized-Solonetz soils of the Brown and Chestnut soil zone, developing in alluvium on fans, footslopes and terraces. It has a light gray silt loam or silty clay loam A2 horizon, with a vesicular crust. This rests on a thick transition B2&A2 horizon of moderate fine platy silty clay loam grading to a grayish brown strong prismatic to blocky silty clay loam B2 horizon, with clear sand grains filtering between the prisms and blocks for as much as 16 inches. This rests on a strong prismatic to coarse and medium blocky B3ca horizon resting over a grayish brown Cca horizon. Gypsum crystals may be found below 20 to 36 inches.

Related and associated series are: Arvada, Absher, Biddle, Forsyth and Galata series. Arvada series differs in having an abrupt A2 to B2 horizon boundary and distinct rounded capped columnar B2 horizon. Biddle series differs in lacking the thick B2&A2 mixed transition horizon and tonguing of A2 between the prisms and blocks of the B2 horizon. Forsyth series differs in lacking the A2 horizon and B2&A2 mixed transition horizon. Galata series differs in being developed in silty clay or clay materials. Absher series lacks the thick B2&A2 transition horizon and is 6 to 8 inches deep to salt flocculated substratum.

A profile as described: 1600 feet north, 800 feet west of SE section corner, Sec. 2, T5S, R53E.

File No.: SCS 232C - 25 JLP 62

<u>Soil Profile:</u> <u>Hydro Silty Clay Loam</u>

A2	0-2"	Gray (10YR 6/2) silt loam; 10YR 3/2 moist; weak fine platy breaking to weak fine crumb structure; soft, friable, nonsticky and nonplastic; noncalcareous; pH 7.0; abrupt boundary.
B2&A2	2-5"	Gray to dark grayish brown (10YR 5/1 and 4/2) silty clay loam; 10 YR 3/2 moist; weak fine platy structure breaking to weak fine granular structure; soft, friable, slightly sticky and plastic; noncalcareous; pH 7.2; abrupt boundary.
B2	5-14"	Grayish brown (10YR 5/2) silty clay loam; 10YR 3/2 moist; strong prismatic breaking to moderate coarse and medium blocky structure; hard, firm, sticky and plastic; thick clay films on all ped faces; noncalcareous; pH 7.4; abrupt boundary.
B3	14-22"	Grayish brown (2.5Y 5/2) silty clay loam; 2.5Y 4/2 moist; strong prismatic breaking to coarse and medium blocky structure; hard, firm, sticky and plastic; thick clay films on ped faces; weakly calcareous; pH 9.0; abrupt boundary.
Cca	22-29"	Grayish brown (10YR 5/2, mottled 8/2) light silty clay loam; 2.5Y 4/2 moist; massive structure; hard, friable, sticky and plastic; very strongly calcareous; pH 8.4; lime seams, nodules and pockets with lime through the soil mass; gradual boundary.
C1	29-43"	Light brownish gray (2.5Y 6/2, mottled with 8/2) silty clay loam; 2.5Y 4/2 moist; massive structure; hard, friable, sticky and plastic; very strongly calcareous; pH 8.4 with lime and gypsum crystals; gradual boundary.
C2	42-63"	Light brownish gray (2.5Y 6/2, mottled with 8/2) heavy silty clay loam; 2.5Y 3.6/2 moist; massive structure; hard friable, sticky and plastic; very strongly calcareous with lime seams; pH 8.4.

<u>Range in Characteristics:</u> Thickness of A2 horizon ranges from 1 to 5 inches and a vesicular crust 1 to 3 inches thick may occur. The A2 horizon ranges in color hues 10YR to 2.5Y with values of 7 to 6 when dry darkening up to a 4 to 3 moist with chroma of 1 to 2. The B2&A2 horizon varies in thickness of 2 to 9 inches with a tonguing of the A2 between prisms and blocks to an average depth of 12 to 16 inches. The sand graining coats the outside of

the blocks and range from clear to stained. The sandgrains thickly coat the peds. The B2 horizon ranges in hues of 10YR to 2.5YR with values of 5 to 4 dry, 3 moist and with chroma of 2. The texture ranges from silty clay loam to clay loam. The B3 horizon is weakly calcareous with no noticeable segregation of lime. At an average depth of 20 to 26 inches a lime segregated horizon appears in seams and splotches with gypsum crystals showing below 26 to 36 inches. The profile is noncalcareous for 26 inches with weakly to strongly calcareous horizons below. The surface has considerable micro pits and shows spotted gray in cultivated fields. Areas lying adjacent to Wibaux soils will take a reddish hue. In the dry, soil, weak coarse prismatic structure extends within 2 inches of the surface.

Mapping Unit Descriptions

23A Hydro silty clay loam, 0-2% slopes

This unit of Hydro silty clay loam occupies nearly level to undulating stream terraces, fans and footslopes 0 to 2 feet fall per hundred feet. It has a micro relief with less than 1 percent barren spots of Absher soils. The unit is 85 to 95 percent Hydro silt loam with 4 to 15 percent inclusions of Arvada, Biddle, Forsyth and Keiser soils. These inclusive soils are unpredictable in the landscape. Profile characteristics for component soils are described under the modal description for each series.

Remarks:

Type location: 1600' N, 800' W of SE Sec. is a body of Hydro silty clay loam in Section 2, T5S, R53E.

23B Hydro silty clay loam, 2-4% slopes

This unit of Hydro silty clay loam occupies gently sloping and undulating fans, stream terraces and sloping footslopes of 2 to 4 feet fall per hundred feet. It has a micro relief with less than 2 percent barren spots of Absher soil. The unit is 85 to 95 percent Hydro silty clay loam with 3 to 15 percent Arvada, Biddle, Forsyth and Keiser soils. These inclusive soils are unpredictable in the landscape. This unit differs from 23A in being more sloping. Profile characteristics for all component soils are described under modal for series of each soil.

Remarks:

Type location: 80-acre area lying in the SW corner of SW¼ Sec. 11 and SE corner of the SE¼ of Sec. 10, T9S, R53E.

23C Hydro silty loam, 4-8% slopes

This unit of hydro silty clay loam differs from 23A and 23B mainly in occupying steeper slopes. It occupies strongly sloping topography of 4 to 8 foot fall per hundred feet. It is characterized as a smooth strongly sloping land with 3 percent or less barren spots of Absher soils and 2 to 15 percent unpredictable inclusions of Biddle, Muggins, and Keiser soils in the landscape. Profile characteristics are same as modal for each component soil.

Remarks:

Type location: 80-acre area 800' N, 800' E of the S¼ corner of Sec. 11, T9S, R53E.

223A Hydro-Arvada loams, 0-2% slopes

This unit consists of a complex of Hydro and Arvada loams. The unit consists of 60 to 80 percent Hydro soils with 20 to 35 percent Arvada soils. These soils are intricately patterned. Other soils that may be found are Absher and Bone soils. These inclusive soils do not exceed 5 percent of the area. The unit occupies level to gently sloping surfaces with 0 to 2 feet fall per hundred feet. Profile characteristics of each individual are same for modal for series.

Ranges in composition are:
- Hydro silt loam - 60 to 80 percent
- Arvada clay loam - 25 to 35 percent
- Absher & Bone soils - 0 to 5 percent

Modal Concept:
- Hydro silt loam - 80 percent
- Arvada clay loam - 18 percent
- Absher & Bond soils - 2 percent

Remarks:

Type location:

223B Hydro-Arvada loams, 2-4% slopes

This mapping unit differs from Unit 223A mainly in occupying gently rolling to undulating slopes, with 2 to 4 feet fall per hundred feet. Other characteristics are same as for unit 223A. Profile characteristics for individual soils are same as for modal for series.

Ranges in composition are:
Hydro silt loam - 60 to 80 percent
Arvada clay loam - 15 to 35 percent
Absher and Bone soils - 0 to 5 percent

Modal Concept:
Hydro silt loam - 80 percent
Arvada clay loam - 18 percent
Absher and Bone soils - 2 percent

Remarks:

Type location:

The series description and the mapping unit descriptions shown above are a part of the Powder River Soil Survey descriptive legend. They were written by John L. Parker of the Soil Conservation Service.

GUIDE FOR COOPERATIVE WORKING ARRANGEMENTS BETWEEN BIA AND SCS RELATIVE TO SOIL SURVEYS

The Bureau of Indian Affairs and the Soil Conservation Service are mutually interested in furnishing farm and ranch people and other users accurate, easily understood information about the Nation's soil and vegetative resources.

Each agency is responsible for collecting, describing, and reporting basic soil and vegetative data about the lands on which it works. It is important that basic data collected by either agency correlate with that being collected by the other.

It is the responsibility of the State Conservationist of the Soil Conservation Service and the Area Director of the Bureau of Indian Affairs to coordinate the soil survey work (soil inventory) of the two agencies at the field level. This includes determination of the areas in which standard soil surveys are to be undertaken cooperatively by the two agencies, priorities for completing and publishing such surveys, and the contributions to be made by each agency. When the requirements of one of the cooperating agencies exceed that of the other, provision will be made by the responsible agency to meet the need. An example of this extended requirement is that of the Soil Conservation Service for publishing standard soil surveys.

Where it is determined that standard soil surveys are to be published for Indian reservations or other areas in which the Bureau of Indian Affairs is performing the field mapping, it may be necessary for the State Conservationist to assign a Soil Conservation Service soil scientist to each such survey area for whatever time may be required to assist with the preparation of soil descriptions, collecting yield data, and other data needed to prepare a manuscript for the published soil survey. Where this is necessary, the Bureau of Indian Affairs will make available the soil survey field sheets, soil descriptions, and soil interpretations that have been prepared. Full recognition will be given to the contributions of each agency in the published soil survey.

In using soil and vegetative data and in presenting them to the general public, it is highly desirable that uniform terminology be used in grouping kinds of soil for different uses. Examples of such groupings are land-capability groupings and range sites. It is the policy of both agencies to use these and other systems as a means of making the information readily available and easily understood by those who need it.

It is recommended that the Area Director (BIA) and the State Conservationist (SCS) meet at least once each year with other Federal and State agencies interested in the collection and use of soil and vegetative information. At this meeting priorities should be established for the initiation, conduct, and completion of cooperative standard soil surveys. Detailed arrangements should be made for the cooperative work to be undertaken during the following year and general plans developed for the next succeeding nine years. Consideration should be given to the people and facilities available for assignment to this cooperative work. Problems of primary interest only to the SCS and the BIA can be resolved at other meetings of the two local agency heads. Agreement is needed on the boundaries of the survey areas, the kind of soil surveys to be made, the design of the mapping legends, soil descriptions, the kinds of soil interpretations to be developed, and uses of the soils information. It is important that agreement in these matters be reached as early as possible for each survey area, preferably before an appreciable amount of field mapping has been done. Technical problems on soil mapping, interpretations, presentation, and use of the results of the work may be referred to the technical staff of each agency for study and recommendations.

A soil survey work plan should be developed for each survey area. It should set forth administrative commitments relating to the work. No two areas are exactly alike. Map detail, scale, availability of data, land ownership patterns, and purpose vary from one to another. Area Directors and State Conservationists will be depended on to exercise judment in the development of work plans to assure that needs are met without overdesigning and unnecessary costs. The Bureau of Indian Affairs, or in the case of a "checker-board" land-ownership pattern, the agency having the greatest immediate need for the data, will initiate the work plan and assume leadership in developing necessary cooperative arrangements for developing jointly a legend and procedural steps for the conduct of the work.

SCS-244a
9-58

U. S. Department of Agriculture
Soil Conservation Service

SOIL SURVEY WORK PLAN

Name of Area: State:

Size of Area:

Description of Area:

Cooperating Agencies:

Base Maps: (a) Kind: (b) Scale

General Publication Plans:

(a) Recommended kind of Map (Mosaic or line):

(b) Recommended scale:

SOILS 4, Rev.
1-30-59

Responsibility for soil survey report:

Reproduction and distribution of copies of field sheets prior to publication:

(Additional copies of soil survey field sheets may be purchased through the local Cartographic unit)

Signed:

Name	Title and Agency	Date

SCS-244c
9-58

U. S. Department of Agriculture
Soil Conservation Service

AMENDMENT
SOIL SURVEY WORK PLAN

Name of Area (or Areas): State:

Purpose of Amendment:

Plans and specifications:

Signed:

Name	Title and Agency	Date

SOILS 4, Rev.
1-30-59

SOIL SURVEY REPORT
POWDER RIVER AREA, MONTANA

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GLOSSARY

ALKALINE SOIL Generally, a soil that is alkaline throughout most or all of the parts of it occupied by plant roots; although the term is commonly applied to only a specific horizon of a soil. Precisely, any soil horizon having a pH value greater than 7.0; practically, a soil having a pH above 7.3.

ALKALI SOIL Generally, a highly alkaline soil, specifically, an alkali soil has so high a degree of alkalinity - pH 8.5 or higher - or so high a percentage of exchangeable solium - 15 percent or higher - or both, that the growth of most crop plants is reduced.

ALLUVIAL SOILS Soils developing from transported and recently deposited material (alluvium) with little or no modification of the original materials by soil forming processes.

AZONAL SOILS A general group of soils having little or no soil profile development. Most of them are young soils. Included in this group are Lithosols, Regosols, and Alluvial soils.

CALCAREOUS SOIL A soil containing calcium carbonate, or a soil alkaline in reaction because of the presence of calcium carbonate. A soil with enough Ca_2CO_3 to fizz when treated with dilute hydrochloric acid.

COLLUVIUM Mixed deposits of soil material and rock fragments near the base of rather steep slopes. The deposits have accumulated through soil creep, slides and local wash.

DEFLOCCULATE To separate or to break up soil aggregates into the individual particles.

DEGRADATION The change of one kind of soil to a more highly leached kind, the change of a Chernozem to a Podzol.

ELUVIATION The movement of material from one place to another within the soil in either true solution or colloidal suspension. Soil horizons that have lost material through eluviation are said to be eluvial; those that have received material are illuvial. Eluviation may take place either downward or laterally according to the direction of water movement.

GENESIS, SOIL The mode of origin of the soil with special reference to the processes responsible for the development of the solum or true soil from the unconsolidated parent material.

HARDPAN A hardened or cemented soil horizon or layer. The soil material may be sandy or clayey and may be cemented by iron oxide, silica, calcium carbonate or other substances.

HEAVY SOIL An old term formerly used for clayey or fine textured soils (the term originated from the heavy pull on the horses when plowing).

HIGH BEARING SOIL A soil that will hold its position and shape under heavy load.

INTRAZONAL SOIL Any one of the great groups of soils having more or less well developed soil characteristics.

LIGHT SOIL An old term formerly used for sandy or coarse textured soils.

LITHOSOL A soil having little or no evidence of soil development and consisting mainly of a partly weathered mass of rock fragments or a nearly barren rock.

LOESS Geological deposit of relatively uniform, fine material, mostly silt, presumably transported by wind. Many unlike kinds of soil in the United States have developed from Loess blown out of alluvial valleys and from other deposits during periods of aridity.

MILLIMHOS Units of conductance.

MORPHOLOGY, SOIL The constitution of the soil including the texture, structure, consistence, color and other physical, chemical, and biological properties of the various soil horizons that make up the soil profile.

NORMAL SOIL A soil having a profile in near equilibrium with its environment; developed under good but not excessive drainage from parent material of mixed mineral, physical, and chemical composition. In its characteristics it expresses the full effects of the forces of climate and living matter.

PARENT MATERIAL The unconsolidated mass of rock material (or peat) from which the soil profile develops.

PED An individual natural soil aggregate such as crumb, prism, or block in contrast to a clod, which is a mass of soil brought about by digging or other disturbance.

PHASE, SOIL The subdivision of a soil type or other classificational soil unit having variations in characteristics not significant to the classification of the soil in its natural landscape but significant to the use and management of the soil. Examples of the variations recognized by phases of soil types include differences in slope, stoniness, and thickness because of accelerated erosion.

PRECIPITATION - EFFECTIVENESS (P-E) INDEX The sum of the 12 monthly quotients of precipitation divided by evaporation.

PROFILE (Soil) A vertical section of the soil through all its genetic horizons and extending into the parent material.

REGOLITH The unconsolidated mantle of weathered rock and soil material on the earth's surface; the loose earth materials above solid rock.

REGOSOL An azonal group of soils that includes those without definite genetic horizons developing from unconsolidated or soft rocky deposits.

SALTS Salts commonly found in soils break up into cations (sodium, calcium, etc.) and anions (chloride, sulfate, etc.) when dissolved in water. Salty soils are formed in arid or semiarid regions in low places or seepy slopes.

SALINE SOIL A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

SERIES, SOIL A group of soils that have soil hoizons similar in their differentiating characteristics and arrangement in the soil profile, except for the texture of the soil surface and are formed from a particular type of parent material. Soil series is an important category in the detailed soil classification scheme. The individual series are given proper names from place names near the first recorded occurrence. Thus, names like Bainville, Glendive, Wibaux and Havre are names of soil series that appear on soil maps. Each name connotes a unique combination of many soil characteristics.

SLICK SPOT A shallow pit often caused by erosion of the A or leached horizon of the solodized - Solonetz. These spots are also called scabby spots and pan spots.

SOLONCHAK SOILS An intrazonal group of soils with high concentrations of soluble salts in relation to those of other soils, usually light colored, without characteristic structural form. These soils are developed under salt loving plants occurring mostly in a subhumid or semiarid climate. In soil classification the term applies to a broad group of soils and is only approximately equivalent to the common term "saline soil".

SOLUM The upper part of the soil profile above the unweathered parent material. In a mature soil the solum includes the A and B horizons.

SUBSOIL The B horizon of soils having distinct profiles. Soils having weakly developed profiles, the subsoil can be defined only as the soil below the plowed layer or its equivalent.

SURFACE SOIL The top 5 to 8 inches of soil ordinarily moved in tillage or its equivalent in uncultivated soil.

TILTH, SOIL The physical condition of a soil in respect to its fitness for the growth of a specific plant or sequence of plants.

TYPE, SOIL A subgroup or category under the soil series based on the texture of the surface soil. Other differentiating characteristics and arrangement in the soil profile and parent material are similar. The name of a soil type consists of the name of the soil series plus the textural class of the soil surface or plow layer. Thus, Glendive fine sandy load is the type within the Glendive series.