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# SOILS AND LANDSCAPES OF MINNESOTA



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## INTRODUCTION

Soils are the basic resource upon which all terrestrial life depends. The bounty from our fields and forests, and in part even from our lakes and streams, is a product of soils. Many of the decisions about resource use in Minnesota are based on the ability of the soils to support that resource use. The productive agriculture of south-central Minnesota is a direct result of the fertile soils and favorable climate in that area. The productivity of Minnesota's forests, too, depends on soil properties.

The map provided on page 6 is not meant to show all soil differences. Rather it is based on the soil taxonomy and reflects the major soil-forming factors operating in Minnesota and the relationship of soils to one another. A map of this scale cannot represent all the intricate patterns of soils present, but can indicate the major soil areas and their characteristics.

# SOIL FORMATION

Soils lie in a complex mosaic across Minnesota and may seem to lack a pattern. This mosaic is not random, however, but is the result of five major environmental elements blended together. The five elements, or soil-forming factors, that lead to the pattern of soils we observe are 1) the parent material, the geologic material from which the soil was originally formed; 2) the climate in which the material is found; 3) the relief or landscape properties upon which that material lay, such as the slope and aspect; 4) the organisms that can potentially live on or in the material; and 5) the length of time during which the previous four elements have interacted. A unique combination of these five factors produces a soil. At any location in the state, that combination of factors may be unique, and produce a unique soil; or a given combination may recur at many locations, producing similar soils.

In soil taxonomy, climate and vegetation determine what order, suborder, and great group a soil is in. Parent material will to a large extent determine the soil family and series (soil survey staff, 1975).

## PARENT MATERIAL

One of the most important elements affecting soil formation in Minnesota is the parent material. The color, texture (number of various size particles, such as sand, silt, and clay), and chemical makeup of the soil are closely related to the color, texture, and chemistry of the parent material. The texture of a soil helps determine its ability to hold and transmit water, thereby determining the wetness of the soil. The moisture and nutrient-supplying properties of the soil greatly affect what kind of plants can grow on it.

Between ten and twenty thousand years ago, Minnesota was largely covered with glaciers. The materials deposited through the direct and indirect action of the glaciers provide the parent material for our soils (figure 1). The material deposited directly by the glaciers is called till, and is an unsorted mixture of material ranging in size from very fine clay to stones and boulders. As the glaciers melted, considerable quantities of water were released. These waters washed the till, removing fine particles and sorting the remaining sands and gravels, which formed glacial outwash sediments. Outwash material is a very common parent material in Minnesota.

In some cases, melt waters collected in low areas, often behind dams of unmelted ice. Lakes were formed that lasted from a few years to thousands of years. One of the best known of these lakes is glacial Lake Agassiz, which occupied the area now known as the Red River Valley in northwestern Minnesota. This lake actually extended, in its early stages, well into northeastern Minnesota. Lacustrine deposits, materials that settled out of glacial lakes, vary from sandy and gravelly at the beaches to clayey near the middle of the lake. The topography of the land that was once covered by these lakes is often subdued, with extensive level areas.

For long periods, both during glaciation and while the ice melted, very little vegetation grew on till and outwash areas. Wind blowing over these areas picked up silt and clay-sized particles and carried them for many miles before depositing them. Areas in both southwestern and southeastern Minnesota are covered by these materials called loess. The loess may rest on older till, on weathered bedrock, or on fresh bedrock.

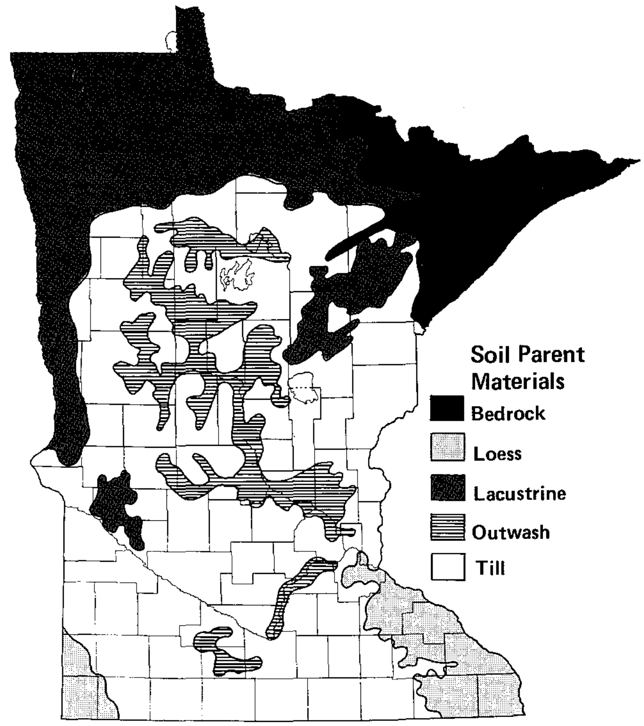


**Figure 1. Parent materials**

In northeastern Minnesota the original bedrock is near the surface so that soil development must take place in the original bedrock under a thin veneer of glacially deposited material.

In addition to differences in parent material associated with differences in mode of deposition, the material carried by the glaciers differed depending on the direction from which the glaciers originated. Glaciers moved over Minnesota from both the northwest and the northeast. Glaciers originating in the northwest passed over limestone deposits in southern Canada and carried materials high in lime. Glaciers from the northeast passed over the Laurentian Shield and other bedrock areas. Depending on the kind of bedrock, these deposits have diverse chemistries but they all lack lime, which affects many other chemical properties.

## CLIMATE

Temperature and moisture, both as averages and as extremes, affect chemical and physical changes that occur in the original parent material. Chemical changes proceed very slowly at low temperatures, and especially during the winter in Minnesota. The mean annual temperature in the state ranges from about 35°F near the Canadian border to about 45°F at the Iowa border. Temperature tends to increase relatively uniformly from north to south (figure 2).

In contrast to temperature, the normal annual precip-

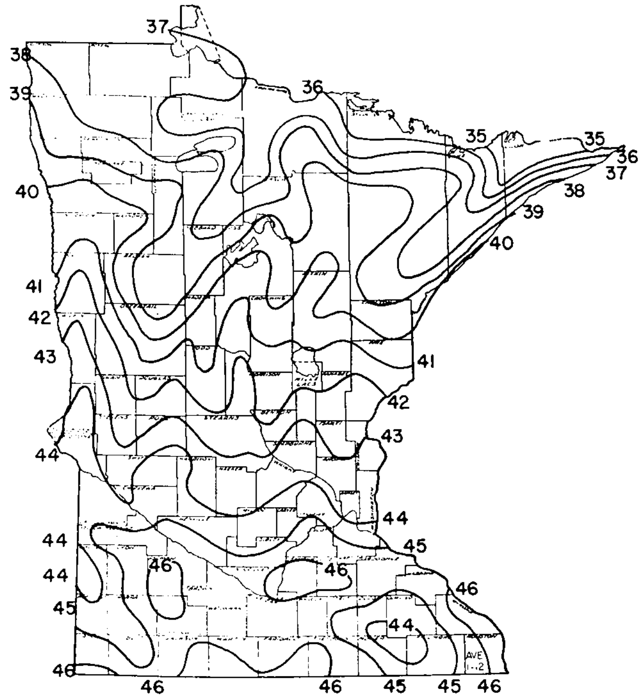

Figure 2. Mean annual temperatures

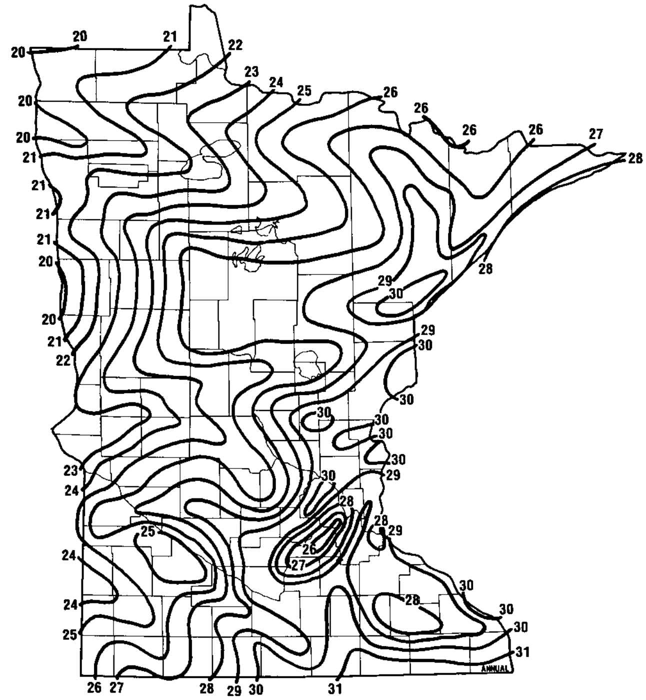

Figure 3. Annual precipitation

itation in the state increases from west to east (figure 3). Areas along the Dakota border receive about 20 inches of rain per year, and those along the Wisconsin border receive about 30 inches per year. Warmer temperatures usually lead to more evaporation of precipitation to the atmosphere so that less is available to cause changes in the soil. Soils in the warmer and dryer areas of the state, for example, retain the high lime concentrations near the surface that they inherited from the parent material. In cooler and moister areas, lime has been removed by water passing through the soil.

## RELIEF

Relief, or the lay of the land, is another element of soil formation (figure 4). It influences both the movement of materials and the soil climate. Local relief affects drainage, runoff, and erosion, and in turn affects the formation and distribution of soils. Steeper slopes contribute to greater runoff, as well as to greater translocation of surficial materials downslope through surface erosion and movement of the soil mass. Soils in depressions and swales collect both water and sediment from higher lying terrain. The loss or addition of water affects the kinds of plants that grow there.

The direction a slope faces also affects soil formation by affecting the soil's climate. A south-facing slope is warmer and dryer than is a north-facing slope in the same locale. As the steepness of the slope increases, this effect becomes more important. In some areas in Minnesota, the borders between forest and prairie vegetation often have forest vegetation and forest soil on the north-facing slopes and prairie soils on the south-facing slopes.

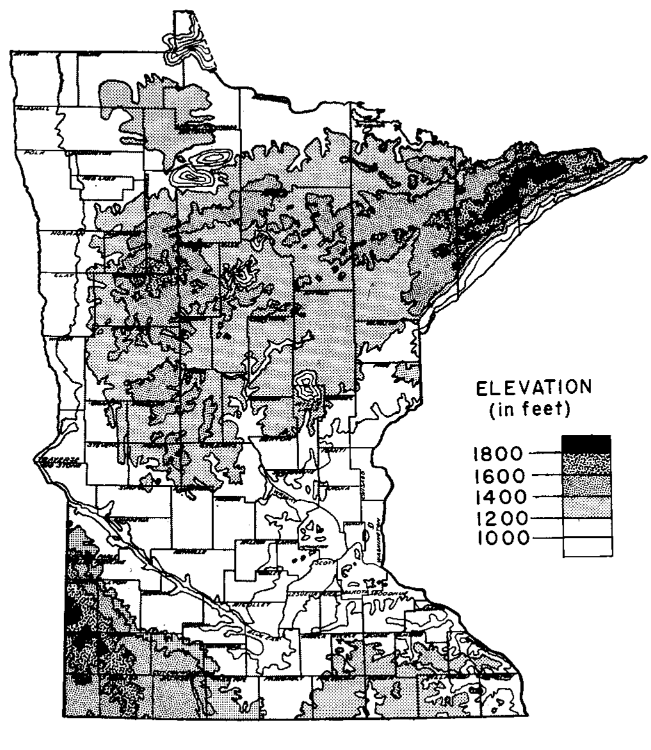


Figure 4. General relief

## LIVING ORGANISMS

Plants, animals, bacteria, and other organisms are active in soil formation. They aid in the breakdown of parent materials and in the formation and decomposition of organic matter in the soil. Vegetation affects soil formation by depositing organic materials in the soil and by transferring plant nutrients from the subsurface to the surface (figure 5).

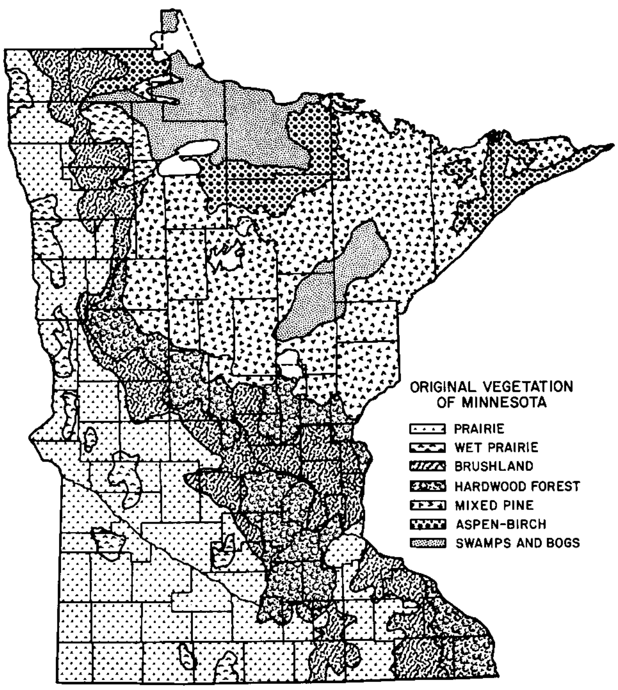


**Figure 5. Original vegetation**

In the prairie areas, fibrous plant roots die and decay each year and supply the surface soil with organic matter. This imparts a dark color to the surface. In forested areas, plant roots are not concentrated in the mineral soil and so the surface is usually a lighter color. Earthworms and other organisms can be very important in mixing soils and incorporating organic matter. Gophers and other small soil-dwelling mammals continually mix the soil.

## TIME

Soil properties are also determined by the length of time during which all the other soil-forming elements have been acting. Although soil properties differ appreciably if we compare very old soils to very young soils, most soils in Minnesota are about the same age. They have all been developing since the glaciers left the state approximately 12,000 years ago, a relatively short time in geological terms. Although the other elements of formation have affected the soils, many of their properties were inherited from the parent material.

# SOIL CLASSIFICATION

To understand and communicate about soils, a standard system of classes or categories was developed. These classes are based on the presence or absence of certain soil properties. Soils can also be categorized by their location (northern versus southern soils), the kind of vegetation growing on them (forest soils versus prairie soils), their topographic position (hilltop soils versus valley soils), or other distinguishing features. The system used to classify soils based on their properties is called soil taxonomy (soil survey staff, 1975). It was developed by the U.S. Department of Agriculture, with the help of soil scientists in universities throughout the country.

The classification of soils 1) aids in remembering the basic characteristics of individual soils, 2) defines relationships between soils, 3) aids in discovering new facts, 4) clarifies relationships between soils and the environment, and 5) aids in the ability to predict properties and uses of an unknown soil.

In soil taxonomy, all soils are arranged into one of ten major units, or soil orders. These orders are further broken down into suborders, great groups, subgroups, families, and series.

Suborders within a soil order are separated on the basis of important soil properties that influence soil development and plant growth. There are 47 suborders presently recognized.

At the great group level, the most significant features of the soil profile are considered. Soil great groups are subdivisions of suborders, and there are 185 great groups recognized.

Each great group is divided into three kinds of subgroups. These are 1) the central concept of the great group (typic); 2) soil properties which intergrade to or are transitional toward other orders, suborders, or great groups; and 3) subgroups with properties that are not representative. There are about 1,000 subgroups recognized.

The next lower category is the soil family. Soil families are separated within a subgroup on the basis of physical and chemical properties that influence plant growth, land management decisions, and engineering purposes. Soil properties include texture, mineralogy, pH, temperature regime, and precipitation pattern. About 4,500 soil families are recognized.

The lowest level recognized is the soil series. Soils comprising an individual series are nearly homogeneous and their range of properties is limited. Soil series are separated on the basis of observable and mappable properties such as color, structure, texture, and horizon arrangement. The series is the level which is generally used to name mapping units of detailed soil surveys completed at scales between 1:24,000 and 1:15,840. There are 10,500 soil series recognized in the United States and over 600 in Minnesota (Buol, Hole, and McCracken, 1981).

The legend on page 7 presents the classification at the suborder level. This level includes a broad climatic grouping of soils, with further separation based primarily on soil wetness.

The soil names throughout the system are made up of syllables called formative elements. Although each of these formative elements may initially seem to have little meaning, they all convey considerable information about the soil. Many of the formative elements come from Greek or Latin roots. The names of all soil orders end in the syllable *sol*, with the first part or prefix of the name giving some indication of the soil properties associated with this broad category of soil. The name of each suborder within an order links another formative element with the prefix from the order name to provide a ready relationship to the order. This system is best understood by examining the legend below.

## SOIL ORDERS AND SUBORDERS IN MINNESOTA

### Mollisols

This order covers a considerable land area of Minnesota and is the basis for the state's productive agricultural base. The formative syllable, *oll*, is derived from the Latin word m*oll*is or soft. Its most distinguishing feature is a thick, dark-colored surface layer that is high in nutrients. It occurs throughout the former prairie areas of Minnesota. The Latin term for soft in its name is descriptive in that most of these soils usually have a rather loose, low density surface. Four suborders of mollisols occur in Minnesota: aquolls, borolls, udolls, and ustolls.

### Alfisols

This order covers a large land area in Minnesota, part of which is now cultivated and part forested. *Alf* is the formative element and is coined from a soil term ped*alf*er. Pedalfers were identified in the 1930s as soils of the eastern part of the United States which had an accumulation of aluminum and iron. The *alf* refers to the chemical symbols for aluminum (Al) and iron (Fe). Alfisols are primarily fertile soils of the forest, formed in loamy or clayey material. The surface layer of soil, usually light gray or brown, has less clay in it than does the subsoil. These soils are usually moist during the summer, although they may dry during occasional droughts. Three suborders of alfisols occur in Minnesota: aqualfs, boralfs, and udalfs.

### Inceptisols

Soils of this order are also common in Minnesota. Here the formative element is *ept*, which comes from the Latin word inc*ept*um or beginning. These soils have changes in properties with depth, but the process of soil formation has been subdued due to lack of intensity of one or more of the five soil-forming factors. Two suborders of inceptisols occur in Minnesota: aquepts and ochrepts.

### Entisols

Soils of this order occur throughout Minnesota. The formative element here is *ent* which refers to rec*ent* soil. Soils developed in recent river bottom alluvium and sandy soils where the parent materials consist of weather-resistant quartz are typical of this soil order. Because of insufficient time or material resistant to weathering, soil properties change very little with depth. Three suborders of entisols occur in Minnesota: aquents, orthents, and psamments.

### Histosols

This is a soil order that has become increasingly important in Minnesota. The formative element in the name is *hist* and comes from the Greek word *histos*, which means tissue. This is an appropriate association because these soils are formed from plant remains in wet environments, such as marshes and bogs. Although they occur throughout most of Minnesota, these soils are found most extensively in the north, in the beds of former glacial lakes. Histosols, or organic soils, have been termed peat and muck.

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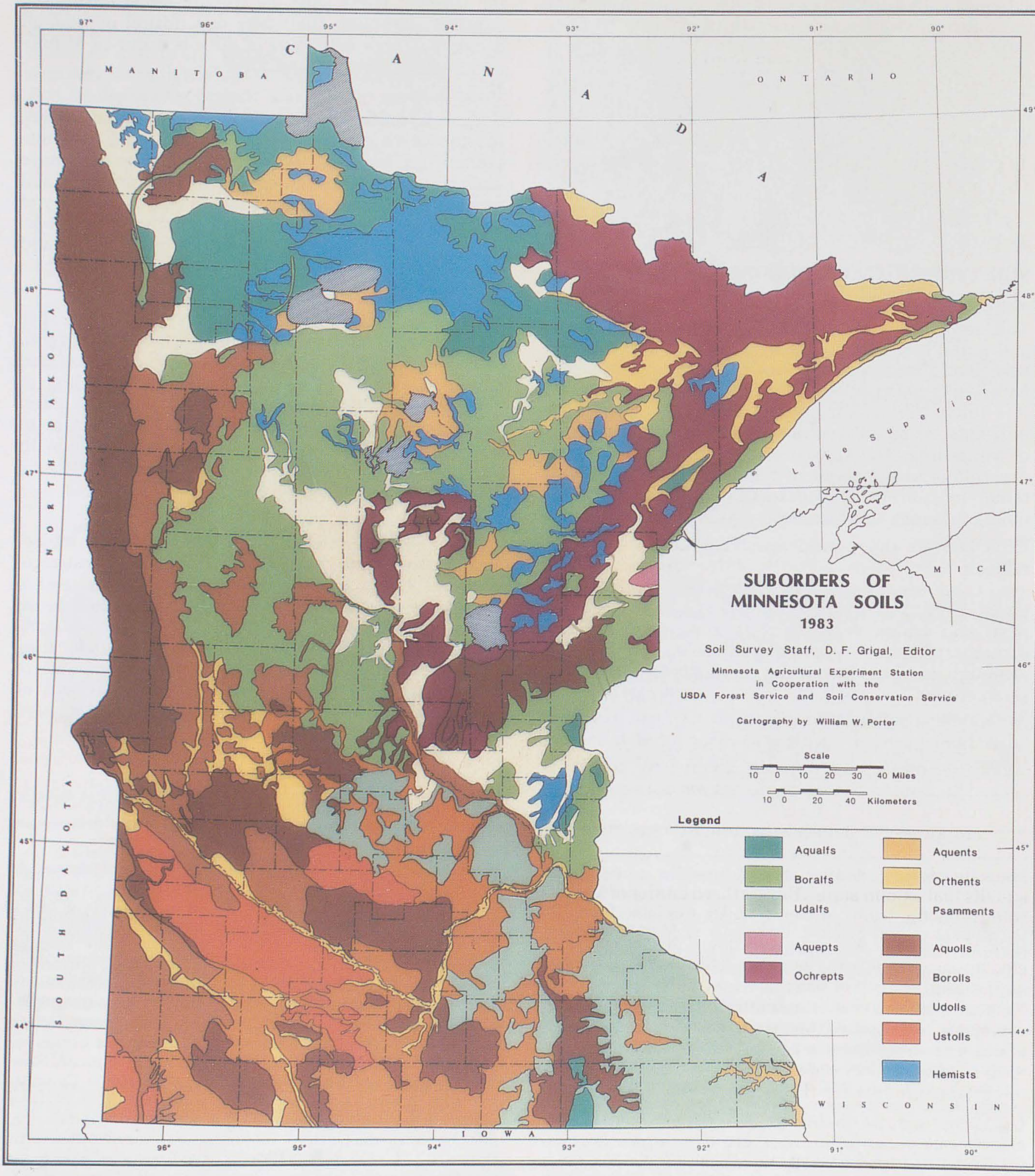
The map on the following page is based on a larger map (1:1,000,000) of state soils, "Soils and Land Surfaces of Minnesota." Limited copies of this map are available from the Department of Soil Science, University of Minnesota, 1529 Gortner Avenue, St. Paul, MN 55108, as part of Soil Series 110, Miscellaneous Publication 11, Minnesota Agricultural Experiment Station.

A more detailed view of state soils can be found in the soil atlas maps and reports. This is a series of 11 maps which provides geomorphic and soil information for the state at a scale of 1:250,000. Soil areas of one square mile and larger are shown. In addition, two reports on soils and geomorphic regions in the Twin Cities metropolitan area are available: *Soil Landscapes and Geomorphic Regions*, AD-MR-2109; and *Interpretations of Soil Landscapes and Geomorphic Regions*, CD-BU-0474. These maps are available from CR Distribution, 3 Coffey Hall, University of Minnesota, 1420 Eckles Av, St. Paul, MN 55108. Further information can also be obtained from the Department of Soil Science listed above.

A detailed view of soils for specific counties of Minnesota can be obtained in county soil survey reports, which are available at scales ranging from 1:15,840 to 1:24,000, or three to four inches per mile. At this level of detail, information about soil on an individual farm can be determined. Many counties in the state have been mapped, and an accelerated program of mapping is continuing with the cooperation of the University of Minnesota's Agricultural Experiment Station and Agricultural Extension Service, the USDA Soil Conservation Service and Forest Service, the Minnesota Soil and Water Conservation Board, and the Department of Natural Resources. State funding for this program comes from the Legislative Committee on Minnesota Resources. Details on the availability of these maps can be obtained from the Department of Soil Science, address above; the USDA Soil Conservation Service, 316 North Robert St., St. Paul, MN 55101; CR Distribution, 3 Coffey Hall, address above; or from the individual Soil and Water Conservation District offices in counties with completed surveys.


SUBORDERS OF
MINNESOTA SOILS
1983
Soil Survey Staff, D. F. Grigal, Editor
Minnesota Agricultural Experiment Station
in Cooperation with the
USDA Forest Service and Soil Conservation Service
Cartography by William W. Porter
Scale
10 0 10 20 30 40 Miles
10 0 20 40 Kilometers
Legend
Aqualfs
Boralfs
Udalfs
Aquepts
Ochrepts
Aquents
Orthents
Psamments
Aquolls
Borolls
Udolls
Ustolls
Hemists
MANITOBA
CANADA
ONTARIO
Lake Superior
MICH
NORTH DAKOTA
SOUTH DAKOTA
IOWA
WISCONSIN

# LEGEND

**Mollisols**

*AQUOLLS* are wet prairie soils. Here the formative element is *aqua*, from the Latin word for water. The *oll* ending shows that this is a mollisol. These are mollisols that occur in areas where the water table is near the surface. The most extensive area of these soils is the Red River Valley, or the bed of an old glacial lake, although they also occur in the beds of other former glacial lakes. They are very productive soils, especially when excess water is removed by drainage. They produce small grains, sunflowers, and sugar beets in northwestern Minnesota, and corn and soybeans in the south.

*BOROLLS* are northern prairie soils. The formation element *bor* refers to *boreas*, a Greek word for the north wind. As the name implies, these are cool prairie soils and are predominant in the western part of the state on better-drained locations. They are often associated with aquolls in lower areas. Because of cooler temperatures, small grains are the most important crop on these soils.

*UDOLLS* are moist prairie soils. The Latin root *udus* refers to humid. These are soils of humid climates. These soils cover much of the southern one-third of the state, and are very productive agricultural soils. The dominant crops on these soils are corn and soybeans.

*USTOLLS* are dry prairie soils. The Latin root *ustus* refers to burnt. These are soils of dry climates, usually hot in summer. They occur in southwest Minnesota in areas where extended dry periods have occurred in the past, and which even now are subject to periodic droughts. They also produce corn and soybeans, although in some years dry conditions limit their productivity.

**Alfisols**

*AQUALFS* are wet forest soils. The *aqua* formative element again implies wetness. Because of their position on the landscape, these soils are wet during much of the growing season. Especially in northern Minnesota they support aspen forests with admixtures of black ash and alder. They are most common in the basins of glacial lakes that formed in the latter part of the Ice Age. The aqualfs that extend across the northern border of Minnesota lie in the basin of glacial Lake Agassiz.

*BORALFS* are soils of the aspen forest. The *bor* formative element again refers to the north. These soils are found in the northern two-thirds of Minnesota. Where they have not been cleared for cultivation, they are now covered by extensive aspen forests. Some of the largest white and red pine trees were found on these soils. Aspen grow well on most of these soils and are an important resource for the forest products industry.

*UDALFS* are soils of the hardwood forests. These are alfisols that occur in the southern one-third of Minnesota. They are similar to the boralfs, but they occur in a warmer climate. Where not cleared for cultivation, they support hardwood forests. Those in the south-central part of the state support forests dominated by sugar maple and basswood, while those in the southeast support forests dominated by oak and some hickories. The area of extreme southeast Minnesota that is dominated by udalfs on ridges contains fertile udolls in the valley floor. The map colors are based on the dominant udalfs.

**Inceptisols**

*AQUEPTS* are wet soils of the mixed conifer-deciduous forest. The formative element *aqua* implies that one of the distinguishing properties of these soils is their seasonal wetness. They are scattered over the northern two-thirds of the state, and support forests of aspen, black ash, willows, and alder. They often occur in association with peatlands.

*OCHREPTS* are soils of the mixed conifer-deciduous forest. The formative element in the name is *ochros*, Greek for pale. These soils primarily occur under forest vegetation in the northern two-thirds of the state. The parent material of these soils is primarily glacial till from the rocky northeastern part of the state, and so these soils are low in lime and contain many large boulders. Now they are primarily covered by aspen forests, although they once were dominated by red and white pine. Aspen on these soils does not grow quite as well as aspen on the alfisols.

**Entisols**

*AQUENTS* are wet, poorly developed soils. These are wet, predominantly sandy soils supporting forest vegetation. They occur in north-central and northwesten Minnesota.

*ORTHENTS* are shallow or poorly developed soils. *Orthos* means true in Greek. These are the true or common entisols. These soils primarily occur in two areas. In northeastern Minnesota, they occupy tops of ridges where outcrops of rock are common. The trees that are present are usually pine. These soils and associated vegetation are picturesque reminders of wilderness. Orthents are also scattered in other areas of the state, especially the west-central and southwest, where glacial deposits have steep slopes and the material is not easily weathered.

*PSAMMENTS* are sandy soils. The formative element, the Greek word *psammos*, means sand, and refers to their dominant property. These soils, occurring both in the forested and prairie areas of the state, are predominantly formed from quartz sand. These sand grains weather very slowly, so that the result of soil formation is simply a sandy soil with little sign of development. In forested areas, these soils support jack pine and oak forests. Toward the south and west, grasses are common beneath the trees and in the east and north, blueberries. Many of these soils are now irrigated and are very productive for a variety of agricultural crops.

**Histosols**

Soil scientists recognize three suborders of histosols, based on degree of change of plant material. With a map of this size, however, it is difficult to separate the three suborders. In the north, histosols support open peatland vegetation or spruce and tamarack forests. In the south, some peatlands are drained for specialty crops such as vegetables and sod.

Estimated area of each order an… d the percent of Minnesota it occupies.

| Order | Suborder | Acres | Percent |
|---|---|---|---|
| Alfisols | | 15,615,000 | 28.6 |
| | Aqualfs | 3,092,000 | 5.7 |
| | Boralfs | 8,248,000 | 15.1 |
| | Udalfs | 4,275,000 | 7.8 |
| Inceptisols | | 4,866,000 | 8.9 |
| | Aquepts | 44,000 | 0.1 |
| | Ochrepts | 4,822,000 | 8.8 |
| Entisols | | 7,790,000 | 14.3 |
| | Aquents | 1,487,000 | 2.7 |
| | Orthents | 2,504,000 | 4.6 |
| | Psamments | 3,799,000 | 7.0 |
| Mollisols | | 19,744,000 | 36.2 |
| | Aquolls | 8,654,000 | 15.8 |
| | Borolls | 4,518,000 | 8.3 |
| | Udolls | 4,639,000 | 8.5 |
| | Ustolls | 1,963,000 | 3.6 |
| Histosols | | 3,156,000 | 5.8 |
| | Hemists | 3,156,000 | 5.8 |
| Lakes | | 3,375,000 | 6.2 |
| | TOTAL | 54,576,000 | 100.0 |

## Selected References and Readings

Additional information about the formation and classification of soils and the vegetation of Minnesota can be found in the following references:

Buol, S.W., F.D. Hole, and R.J. McCracken. 1981. *Soil Genesis and Classification*. 2nd ed. Iowa State University Press, Ames. 404 pp.

Heinselman, M.L. 1974. *Interpretation of Francis J. Marschner's map of the original vegetation of Minnesota*. 1:500,000 map and text. USDA Forest Service, North Central Forest Experiment Station, St. Paul, MN.

Sims, P.K. and G.B. Morey, eds. 1972. *Geology of Minnesota: A Centennial Volume*. University of Minnesota, Minnesota Geological Survey, St. Paul. 632 pp.

Staff, USDA Soil Conservation Service. 1975. *Soil Taxonomy*. U.S. Department of Agriculture handbook 436. U.S. Government Printing Office, Washington, D.C.

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