Development and Classification of Soils

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DEVELOPMENT AND CLASSIFICATION

OF SOILS

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1. Evolution of Mineral Soils. The parent materials from which soils are produced are formed through weathering of rocks. Both disintegration and decomposition are involved in this transformation, the important forces being temperature, wind, ice, gravity, water, oxygen, and carbon dioxide.

Concomitant with or following the formation of parent material, plants appear in the mass, and the trends in weathering become modified and intensified. The plants eventually die, fall back into the earth, and are decayed by the microbes. Carbon dioxide both from living plant roots and from the decaying organic matter increases the rate of decomposition of the mineral material. Weathering may also be augmented by the action of intermediate products of organic decay. Substitution of iron, magnesium, and aluminum in the crystal lattice of clays may occur at this point, and new clays may be synthesized. Humus soon appears and becomes intimately mixed with the mineral colloids. This humus-clay mixture covers the more inactive soil particles, and begins to dominate such soil properties as water adsorption and movement, and to modify the rate of weathering through adsorption of gases, water and ions. It is now evident that the changes occurring in the upper regolith are accomplished by biological as well as by the physical and chemical forces noted above.

While a change in kind of weathering produces a mass of material different from the original parent material, other processes further change its appearance. Layers or horizons begin to develop. The surface is weathered more than the lower layers, and humus imparts a brown to black coloration to it. Water from rains or snows percolates through the mass, and soluble materials as well as colloidal material may become eluviated and, subsequently, deposited in the lower layers. Through the actions of wetting and drying, freezing and thawing, organic matter, plant roots, and ions such as calcium, the primary particles may become aggregated, and definite structural characteristics may appear in one or more horizons.

As a result, then, of destructive and constructive actions, rocks may be converted into soil. The horizons that are formed have a certain color, depth, texture, chemical composition, organic matter content, structure, consistency, and weight -- properties characteristic of itself and different from any other horizon in the same soil or in other soils, even though they be adjacent. A new natural body has come into being, i.e., soil.

2. Soil Forming Factors. The general action of soil formation as pictured in the preceding paragraph has been discussed in detail in a previous lecture. However, no attempt was made at that time to account for the causes of specific differences in profiles, for instance as one would find them in crossing this country from the Pacific to the Atlantic. It should be kept in mind that about the same general physical, chemical, and biological reactions are involved in the development of all soils in all regions. Differences in profile appearance are not so much correlated with different kinds of weathering, as with differences in intensity of weathering, vegetation, parent materials and topography. The factors influencing the kind of profile formed have been summarized by Shaw as follows:

$$S = M(C + V)T \pm D$$

This identity states that soil (S) is formed from parent material (M) through the action of climate (C) and vegetation (V) acting through a period of time (T). It may or may not be influenced by erosion and topography (D).

Parent Material

The kind of parent material has an important bearing on the nature of the soil evolved, especially in regard to the coarseness or fineness. Soil materials originating from granite, quartzite, sandstone, slate, gneiss, sandy limestone, sandy shales, and conglomerate tend to result in sandy or coarse soils. Fine-textured soils are usually formed from weathered limestone, shale, feldspar, micas, dolomite, and the secondary minerals as hematite, clays, and talc. Loess, a mixture of fine-grained minerals, perhaps of many kinds, results in fine-textured soils. A general map giving the distribution of parent materials in the United States is given in Figure 1. The glacial accumulations are mixtures of sandy to gravelly materials of many different kinds. The great plains material consists also of many different parents, but probably windlaid deposits, shales, and sandstones are the most abundant.

Climate

Climate has a profound influence on soil genesis. The relations of climate to degree of weathering of parent materials have already been emphasized. Suffice it to say that a variation in temperature affects not only the decay of organic matter, but also the speed of chemical, bio-chemical, and physical reactions.

Of great importance to soil genesis are the processes of eluviation and illuviation. Any factor that affects the amount of water percolating through a soil will necessarily influence the development of horizons. Consequently, the total rainfall, temperature, relative humidity, and length of frost-free season will affect it. For instance, with a given rainfall, the amount of water left free to percolate through the soil will be increased with an increase in relative humidity, a decrease in temperature, a long frost-free season, and a decrease in rate of fall. Rainfall-evaporation lines (effective precipitation) of similar ratio conform more nearly to soil group boundaries than any other climatic data. The distribution of precipitation for the United States is given in Figure 2, and for Colorado (in more detail) in Figure 3. It should be pointed out that climate is an important factor in determining the types of native vegetation which also have an important bearing on the development of soil.

LEGEND

UNCONSOLIDATED DEPOSITS

Glacial Accumulations

Gc

Highly Calcareous

Gn

Slightly or
Non-Calcareous

Marine Deposits

M

Marl and Chalk

Sc

Sands, Clays and
Limestones

Lake Deposits

L

Windlaid Deposits

Lo

Loess

S

Sands

Great Plains Material

P

Alluvial Fans, Other Desert Accumulations and Gravels

Af

River Alluvium

A

RESIDUAL ACCUMULATIONS from

Crystalline Rocks

C

Sandstones and Shales

Ss

Limestones

Li

Sandstones, Shales And Limestones

Ssl

Mountains

Mo

FIGURE 1. DISTRIBUTION OF PARENT MATERIALS OF SOILS

Adapted from Atlas of American Agriculture (1935)

LEGEND

UNCONSOLIDATED DEPOSITS

Glacial Accumulations

Gc — Highly Calcareous

Gn — Slightly or Non-Calcareous

Marine Deposits

M — Marl and Chalk

Sc — Sands, Clays and Limestones

Lake Deposits

L

Windlaid Deposits

Lo — Loess

S — Sands

Great Plains Material

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Alluvial Fans, Other Desert Accumulations and Gravels

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River Alluvium

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RESIDUAL ACCUMULATIONS from

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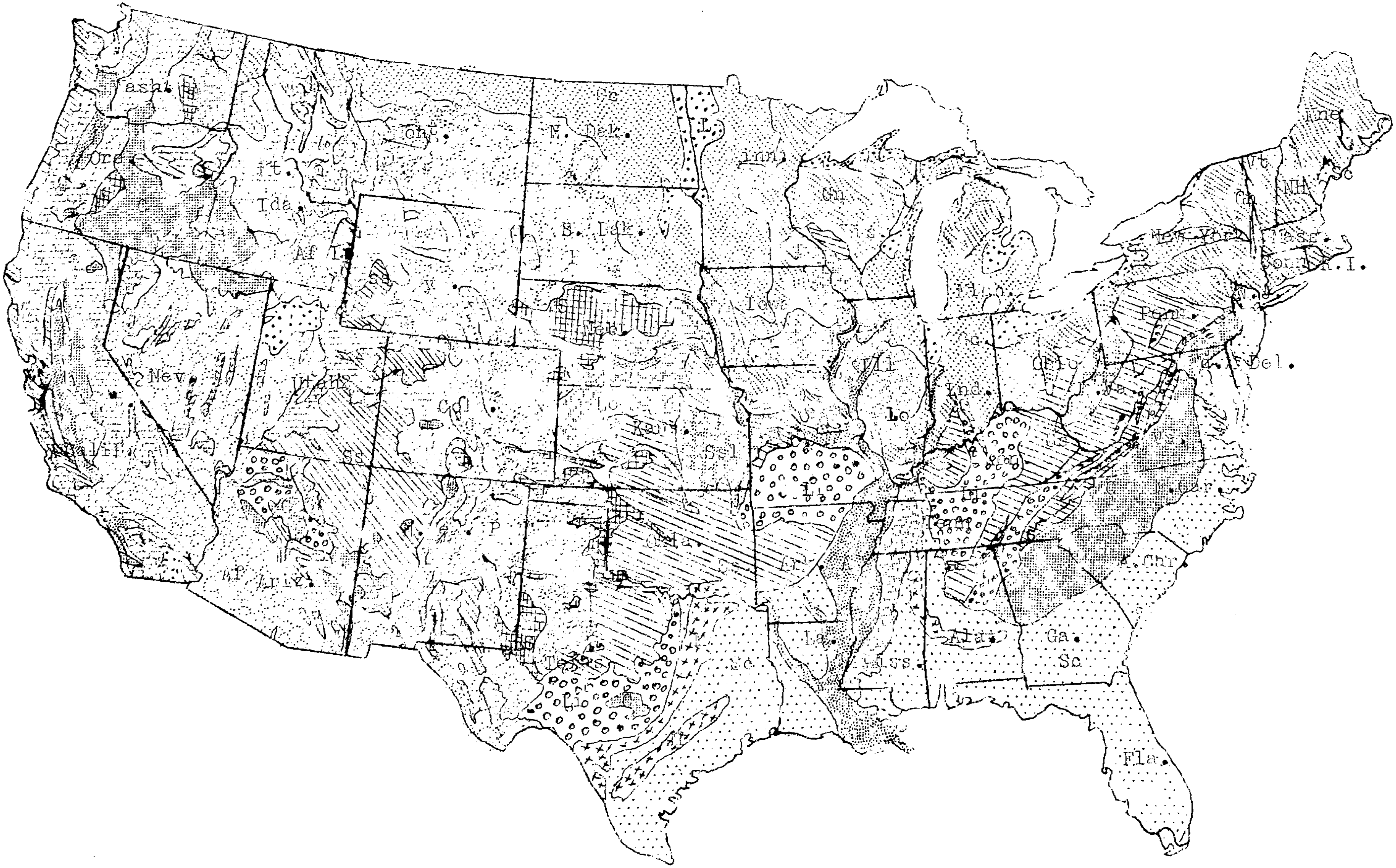
Mountains

Mo

FIGURE 1. DISTRIBUTION OF PARENT MATERIALS OF SOILS



Adapted from Atlas of American Agriculture (1935)

LEGEND

- Under 10 inches
- 10 to 15 inches
- 15 to 20 inches
- 20 to 30 inches
- 30 to 40 inches
- 40 to 50 inches
- 40 to 60 inches
- 50 to 60 inches
- Over 60 inches

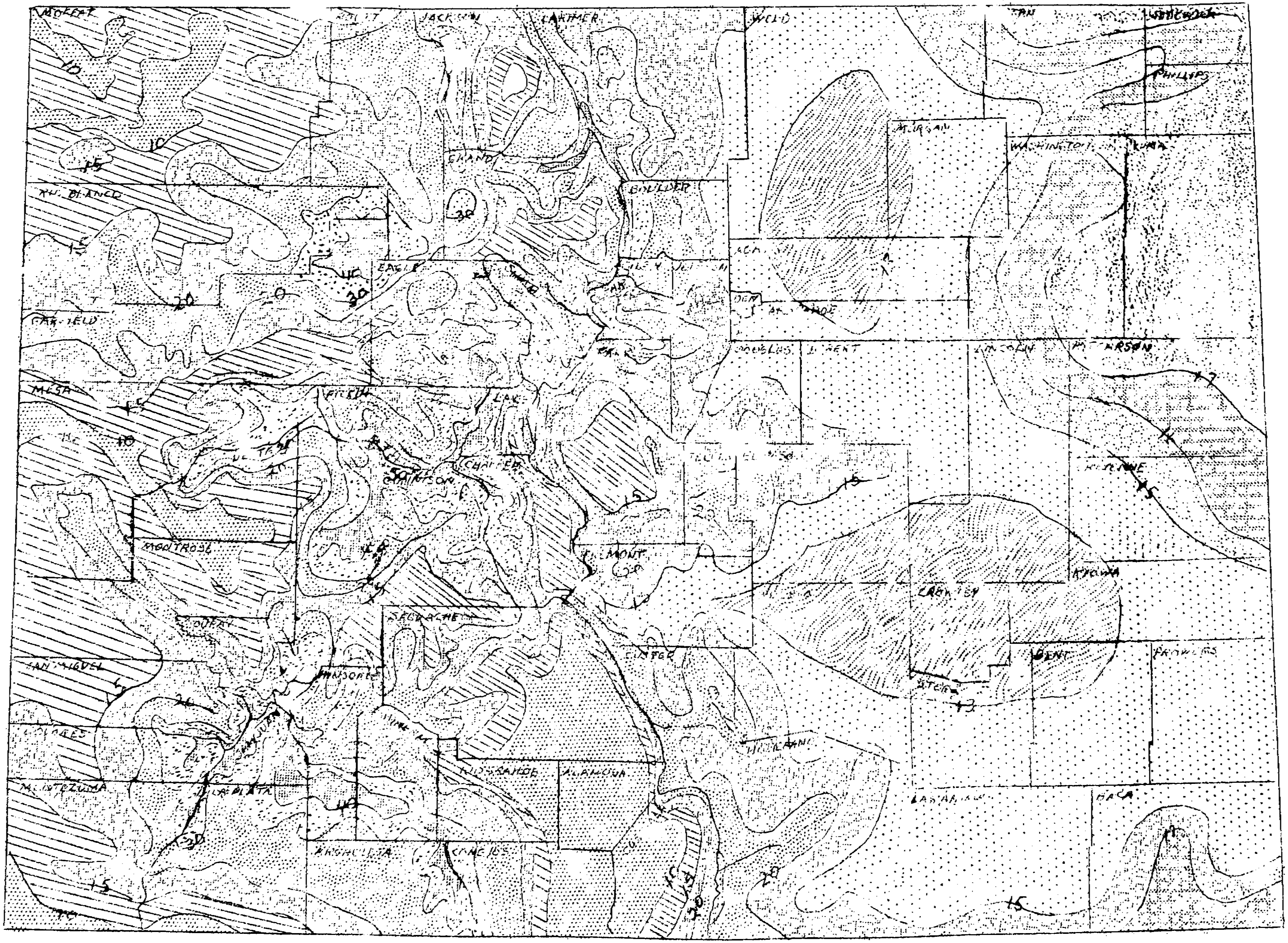
FIGURE 2. DISTRIBUTION OF PRECIPITATION IN THE UNITED STATES

Adapted from Atlas of American Agriculture (1935)

LEGEND

Under 10 inches	17 inches
10 to 15 inches	15 to 20 inches
13 inches	20 to 30 inches
13 to 15 inches	30 to 40 inches
15 to 16 inches	40 to 50 inches
16 to 17 inches	Over 50 inches

FIGURE 3. DISTRIBUTION OF PRECIPITATION IN COLORADO



Adapted from Colorado State Planning Commission and Colorado Water Conservation Board

Vegetation

That organic matter influences soil development is already clear when one considers that synthesis or constructional processes begin with the appearance of plants in the soil materials. Further effects can also be attributed to plants. For instance, shallow-rooted grasses take more water from the surface soil than deep-rooted trees, and less remains to percolate to the lower soil, and such soils are less leached. The type of plant cover also influences the base content of the surface soil. Conifers have a low base requirement, therefore, upon decay of litter from such trees, few bases are returned to the soil. Because of the latter, and due to deep penetration of the water in soils thus forested, the soil generally becomes acid. Litter from deciduous trees is high in bases, and their liberation upon decay helps to keep the soil less acid. Grass vegetation is still higher in bases and the soils usually are not highly leached and acid. Generally, plants can be said to "mine" nutrients found in the B horizons and return them to the surface soil upon decay. As noted above, this effect varies with the type of plant.

Soils formed under deciduous forests usually have a shallow topsoil that is medium in organic matter, while soils formed under coniferous forests have shallow surface soils that are low in organic matter. Coniferous litter tends to accumulate on top of the mineral soil, while deciduous litter tends to become mixed with it to a greater extent, due to its more rapid rate of decay and due to incorporation by earthworms.

Thick black surface soils occur under tall grass cover, while fairly thick dark brown surface soils are formed under short grasses.

The native vegetation of this country is given in Figure 4, while a semi-detailed vegetative map for Colorado is presented in Figure 5.

Time

It takes considerable time for the constructional forces in soil genesis to come to equilibrium with its environment. When this does occur, a well-developed or "mature" profile occurs. Thus the time factor refers to degree of development of a profile and, depending on the degree of development, soils are variously described as recent, young, immature, semi-mature, and mature. Recent, young, and immature soils resemble the parent materials, that is, they still have "inherited" characteristics. Semi-mature and especially mature soils have "acquired" a new appearance, and after such old soils may give no hint of the character of the parent material from which they were formed. Fresh deposits of alluvium, deltas, lake and ocean deposits, sand dunes, and recent deposits of rock material that still have inherited characteristics are good examples of recent or young soils. The time factor does not necessarily refer to a "period of years" for soils formed from two different parent materials, lying side by side in the same environment, may be in different stages of development even though they have been weathered for the same length of time. Difference in maturity or age may be associated with differences in kind of parent material, slope of land, drainage, etc.

LEGEND

Forest Vegetation (Western)

- I — Pinon-Juniper (S.W. Coniferous Woodland)
- II — Lodgepole-Spruce-Pine
- III — Pacific Douglas Fir
- IV — Yellow Pine
- V — Chaparral

Forest Vegetation (Eastern)

- VIII — Spruce-Fir
- IX — Jack, Red, and White Pines
- X — Northeastern Hardwoods
- XI — Oak Hickory
- XII — Oak-Chestnut
- XIII — River Bottom Forest
- XIV — Longleaf-Loblolly-Slash Pines
- XV — Oak-Pine

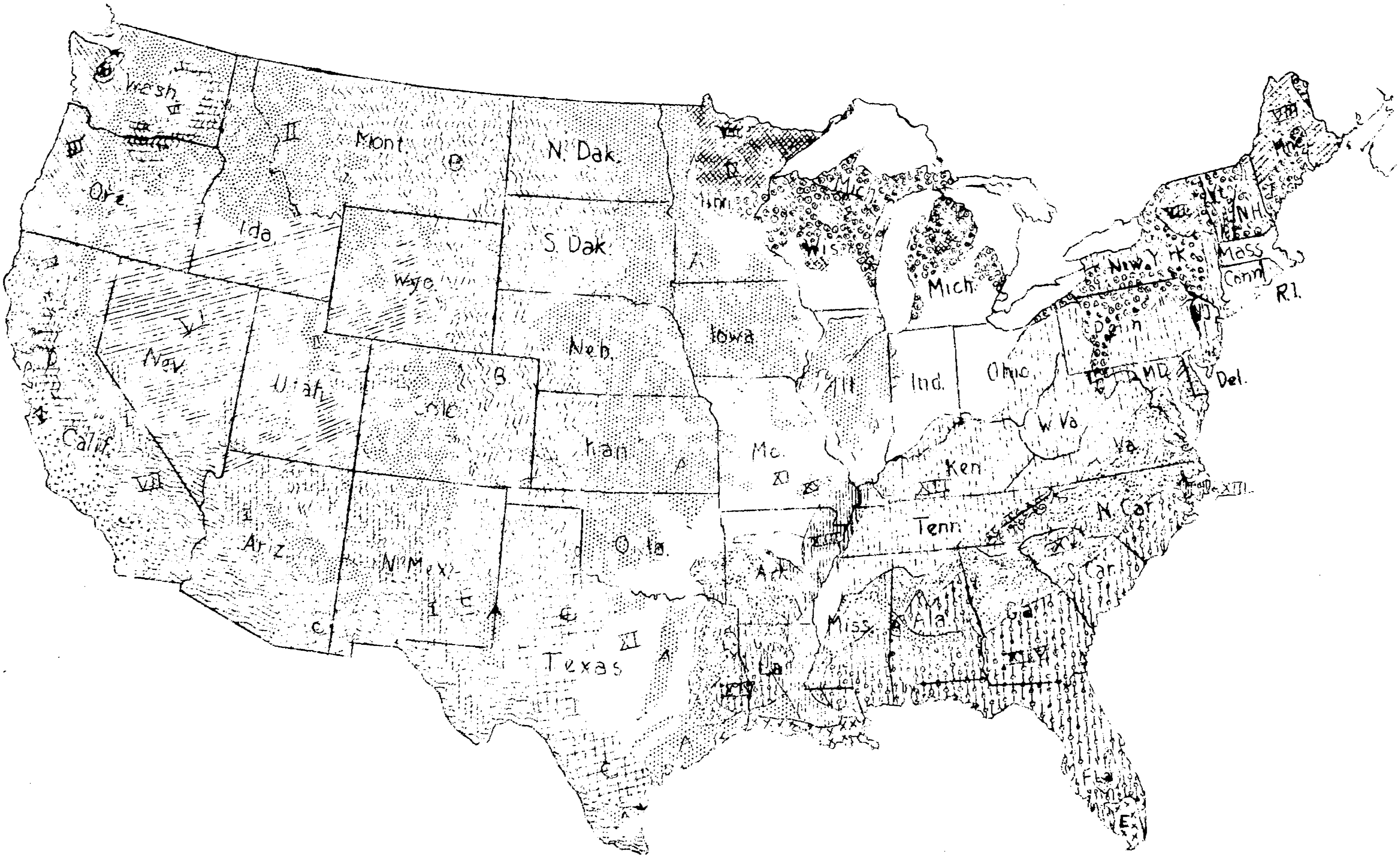
Desert Shrub Vegetation

- VI — Sagebrush
- VII — Creosote Bush

Grass Vegetation

- A — Tall Grass
- B — Short Grass
- C — Mesquite Grass
- D — Bunch Grass
- E — Marsh Grass

FIGURE 4. NATIVE VEGETATION OF THE UNITED STATES

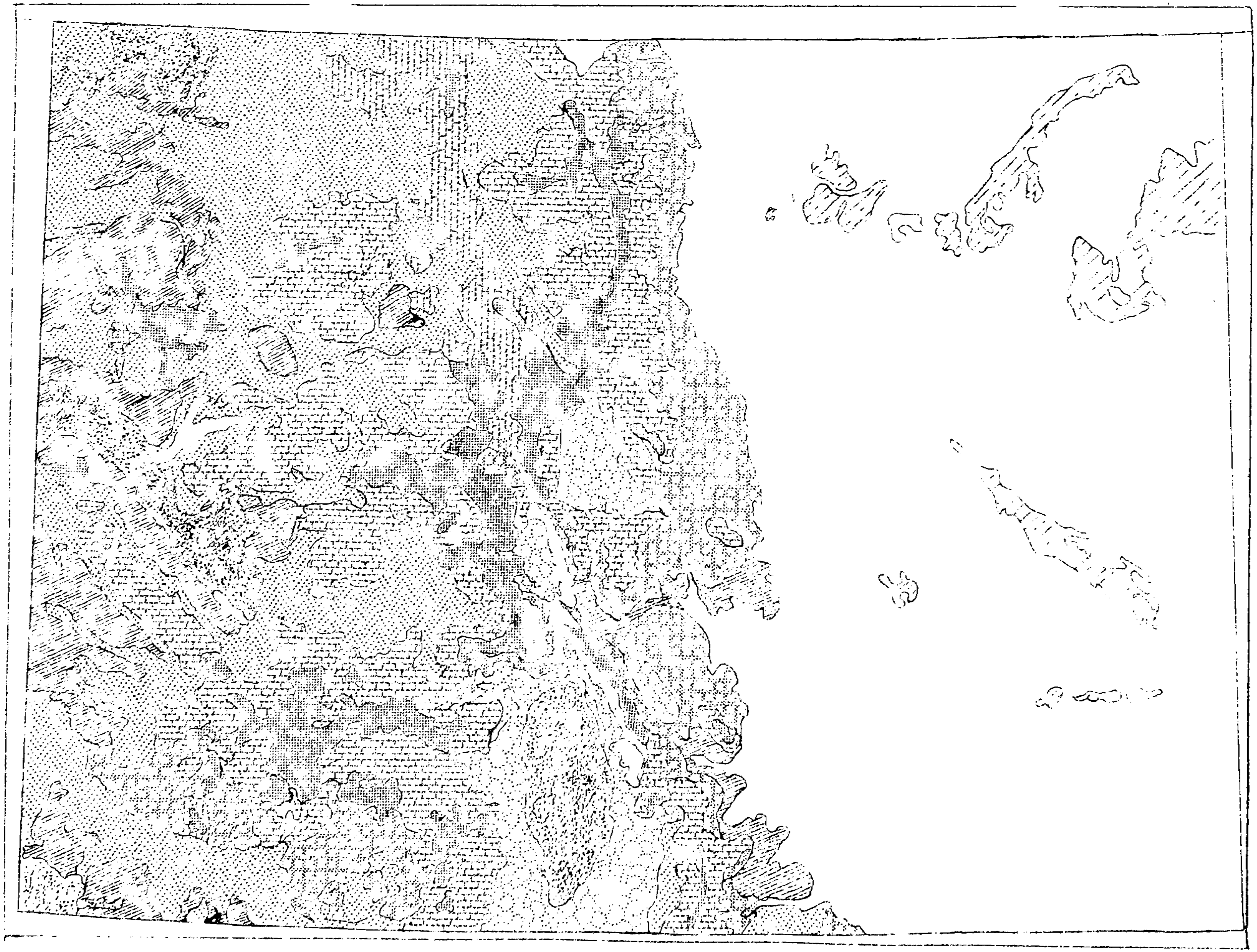


Adapted from Atlas of American Agriculture (1935)

LEGEND

- Shortgrass
- Sagebrush-Chaparral
- Other Grassland
- Pinon-Cedar
- Sandhill
- Montane Forest
- Shadscale-Greasewood
- Subalpine
- Alpine

FIGURE 5. NATURAL VEGETATION OF COLORADO



Adapted from map prepared by Melvin Morris, Range Management Section, Colo. Agri. Exp. Sta. 1935
Traced by G. Hovey, Feb. 1937. Department of Range and Pasture Management.

Erosion and Topography

Normal zonal soils are found on undulating uplands. The drainage is good but not excessive and removal of soil by geological erosion is counterbalanced by further weathering of the parent material. The thickness of the solum remains constant. On steep slopes destructive erosion may occur, and the soil becomes thin and less productive. A badly eroded soil is said to have a "truncated" profile.

Depressions or basins encourage abnormal climatic forces. Runoff may accumulate in such spots, and if the drainage is good, excessive leaching may occur. If drainage is poor, bogs and swamps form. In semi-arid and arid regions lowland areas often become saline, especially if drainage is poor.

Erosion and topography, therefore, may have a profound influence on the development of soils.

3. Nomenclature of Horizons. The principal characteristic that distinguishes soil from an ordinary mass of rock particles is its profile which shows the presence of more or less well-defined horizons. The more mature a soil becomes, the more evident become the horizons. The following diagram shows a hypothetical profile having all of the principal horizons. All of these zones, of course, will not be found in every soil.

Zone of organic matter accumulation	A_{000}	L	Loose leaves - undecomposed litter
	A_{00}	F	Partially decayed litter
	A_0	H	Humus layer; rather completely decayed
Zone of eluviation	A_1		Dark colored; relatively high in organic matter
	A_2		Light colored; region of maximum leaching
	A_3		Transitional to B, but more like the A
Zone of illuviation	B_1		Principal zone of accumulation. May contain humus, iron, clay, lime, salts
	B_2		Zone of accumulation, but less so than the B_1
Products of rock weathering	C		Parent material

In dry regions, it is often very hard to divide a soil into A and B horizons without a detailed chemical analysis. Consequently, layers in such soils are often described and given a location in the profile by indicating their depth from the surface.

The symbol A_0 is reserved for layers of incorporated organic matter lying on top of mineral salts. Sub-horizons within this layer are named as indicated in the diagram, or are given the letter designations L, F, and H. The "L" layer is the litter of recent times which is practically undecomposed. As the lower part of the L layer decays a new mass of material is evolved. It is partially decayed organic matter and so many plant parts can still be recognized. This is the zone of fermentation or "F" layer. The "H" horizon is the zone of humus accumulation. No plant parts can be identified. This is the zone of accumulation of the end products of organic matter decay -- especially humus.

The A and B horizons collectively are known as the "solum."

4. Soil Forming Processes. Depending upon the nature of the environment, there are seven general processes of soil development: podzolization, laterization, calcification, salinization, solonization, solodization, and gleization. The zonal soils are produced by modifications of the first three processes, and the last four are operative in the genesis of intrazonal soils.

Podzolization

Podzolization occurs in areas of high humidity and forest vegetation. This process is involved in the formation of several soil groups, but is typical in northern humid regions and in high mountains under coniferous vegetation. Under such conditions, a highly eluviated profile having a matted organic layer on top of the solum appears.

The salts and bases are first leached from the soil and it becomes very acid. Organic acids from the decaying forest litter along with carbon dioxide hasten the decomposition of the soil particles, and iron and aluminum go into solution or suspension and are carried down in percolating water. Humus is also illuviated. A dark brownish B_1 horizon is formed through the illuviation of the iron, aluminum, and humus, and a lighter brownish-yellow B_2 horizon results from the deposit of iron and aluminum. Due to the excessive leaching of the surface soil, a gray or whitish-gray A horizon results. Often the top of the A horizon becomes intermixed with humus from the organic accumulation on the surface of the soil and necessitates its division into the A_1 and A_2 horizons. Because of the intense acidity developed in such soils, fungi predominate all others forms of micro-organisms.

The characteristic features of a podzolized soil include the ashy gray A_2 horizon underlain by a dark brownish B_1 zone. The A_2 horizon is often called the "bleicherde," while the B_1 zone is called an "orterde", unless it is tightly cemented by the precipitated iron, aluminum, and humus, in which case it is called an "ortstein."

Podzolized soils are usually low in bases and are thus quite acid. An unincorporated layer of organic matter occurs on the surface, and fungi are the most abundant of the microbes present. Highly podzolized soils are quite infertile for farm crops, but sustain forest cover, especially of the coniferous type, since such trees have a low requirement for bases such as calcium and potassium.

Most of the soils of eastern United States are influenced by this process. However, the intensity of podzolization decreases from north to south. The soil groups involved are Podzols, Gray-Brown podzols, Brown podzols, Prairie, and Red and Yellow podzolic soils. Typical profiles for some of the latter are presented in Figure 6. See Table 1 for general conditions of formation of these soils.

Laterization

Laterization is essentially the rather complete weathering of minerals, and its full development results in the formation of silica, iron oxide, and aluminum oxide. It occurs in humid areas of high rainfall, warm to hot climates, and under forest, semi-tropical, and tropical vegetation.

Due to the intense weathering, original minerals almost entirely disappear and iron oxide, aluminum oxide, and silica begin to appear. Bases are also rapidly released. Luxuriant vegetation grows, and it decays rapidly when dead, liberating relatively large quantities of bases to the soil. Consequently such soils do not become highly acid. Due to a lack of acidity, silica is leached out of the surface and iron and aluminum oxides (as well as resistant minerals) remain in the surface.

Laterization results in soils high in iron and alumina and low in silica. The colloids are thus of the hydroxide type and have a low base exchange capacity, water adsorbing capacity, plasticity, and cohesion. These soils are often very deep (up to 100 feet) and typically red with mottlings of red, light gray, buff, or white colors. The subsoils usually grade into yellowish colors. Hard red crusts of iron oxide are commonly found in the profile. These soils are rather deficient in plant nutrients, and successful cropping depends upon the liberal application of fertilizers.

As laterization proceeds, and hydrolysis decreases, the soil may become acid and podzolization may occur. This is especially true if the parent material contains considerable acidic rock material. This is what has happened in the southern and southeastern United States. Red and yellow podzolic soils have been formed. Thus, these soils have been influenced by two processes, laterization and podzolization. (See Figure 6 and Table 1.)

Calcification

Calcification occurs in regions of moderately low to low rainfall under grass or brush vegetation. The process simply refers to the redistribution of lime (Ca and Mg carbonates) in the soil profile without its complete removal. Because of low rainfall, the percolation of water through the profile is not sufficient to remove the lime. However, through carbonation, the bicarbonates of calcium and magnesium go into solution to a limited extent and are leached downward where they become illuviated. Therefore, due to this process,

Figure 6. Typical Profiles - Pedalfers

Podzol

Aooo, Aoo, Ao (L, F, H)	Organic layer pH 4.0-5.0
A1	Dark gray to black
A2	Ashy white to gray low in Fe & Al; pH 4.5-5.0
B1	Dark brownish red accumulation of Fe, al and humus pH 5.5
B2	Light brownish yellow Some Fe and Al deposited. pH 6.0
C	Parent material (often acidic rock)

Gray Brown Podzol

Ao	Shallow organic layer
A1	Gray-Brown; humus mixed.
A2	Light grayish brown or grayish yellow. Lime removed Some Fe and Al removed
B	Reddish to yellowish red. Some Fe deposited Very low in organic matter.
C	Parent material (often basic rock)

Red Podzolic

Ao	Shallow organic layer
A1	Brownish due to humus
B	Very red; often mottled with iron crusts. (Yellowish in yellow podzolic soils)
C	Parent material (Commonly granite gneiss and sands)

Prairie

A	Black due to humus very deep. No free lime. pH 5-7
B	Lighter color Buff to yellowish No free lime pH 5-6
C	Parent Material

a zone of lime accumulation occurs some place in the profile. The grass itself is high in bases, and when this cover dies and decays, the ash is returned to the soil. This further tends to keep the soil high in bases.

The colloids of such soils are high in exchangeable calcium which tends to promote aggregation of the soil particles and to reduce the eluviation of clay colloids to some extent. The soils are generally very productive, providing sufficient water is available. The Chernosem, Chestnut, Brown, Sierozem, and Desert soils are formed by calcification. (See Figure 7, Table 1.)

Salinization

Salinization is the process of accumulation of various kinds of salts in the soil, including the sulfates, chlorides, and nitrates of sodium, potassium, calcium, and magnesium. Such salts are known as white alkali salts.

Salts tend to accumulate in basins or depressions. They may be washed in from the surrounding area, or brought up into the soil as water rises from lower layers by capillarity. Drainage facilities are poor, otherwise salts would be washed from the soil. Because of the excess salts, the soil colloids are highly flocculated; the soil itself is quite structureless. Streaks and spots of salts are present throughout the profile, and often thick crusts of salts appear on the surface of the soil. Such soils are not highly alkaline, but the productivity is poor due to the excess salts.

Soils containing accumulations of white alkali are called "saline" or "Solonchak" soils. Such soils occur primarily in semi-arid to arid regions.

When drainage conditions on saline soils are improved, the salts are gradually dissolved and are leached away. If calcium salts predominated the original soil, a calcium soil is formed upon drainage, and the new profile will probably be typical of the normal soil of that area. However, if a sodium Solonchak is drained an entirely different soil is formed. This process is discussed in the next section. (See Figure 7, Table 1.)

Solonization

As a sodium Solonchak is drained, soluble salts are removed, the colloid becomes highly saturated with sodium, and the colloids become rather deflocculated. This is the process of solonization, and the resulting soil is called a "Solonetz" or "alkaline" soil.

Such soils are highly basic, and have a structureless surface soil and a hard prismatic or columnar subsoil. The sodium colloids hydrolize to form sodium hydroxide and subsequently sodium carbonate. The total salt content is not high, the principal ones being the carbonates and bicarbonates of sodium (and potassium). Such salts are called "black alkali" salts since they are very alkaline and tend to dissolve or deflocculate the soil humus which gives them a black to brownish coloration.

These soils are very unproductive due to their high alkalinity. Reclamation of such soils often involves the addition of gypsum to them as a source of active calcium.

Figure 7. Typical Profiles - Pedocals

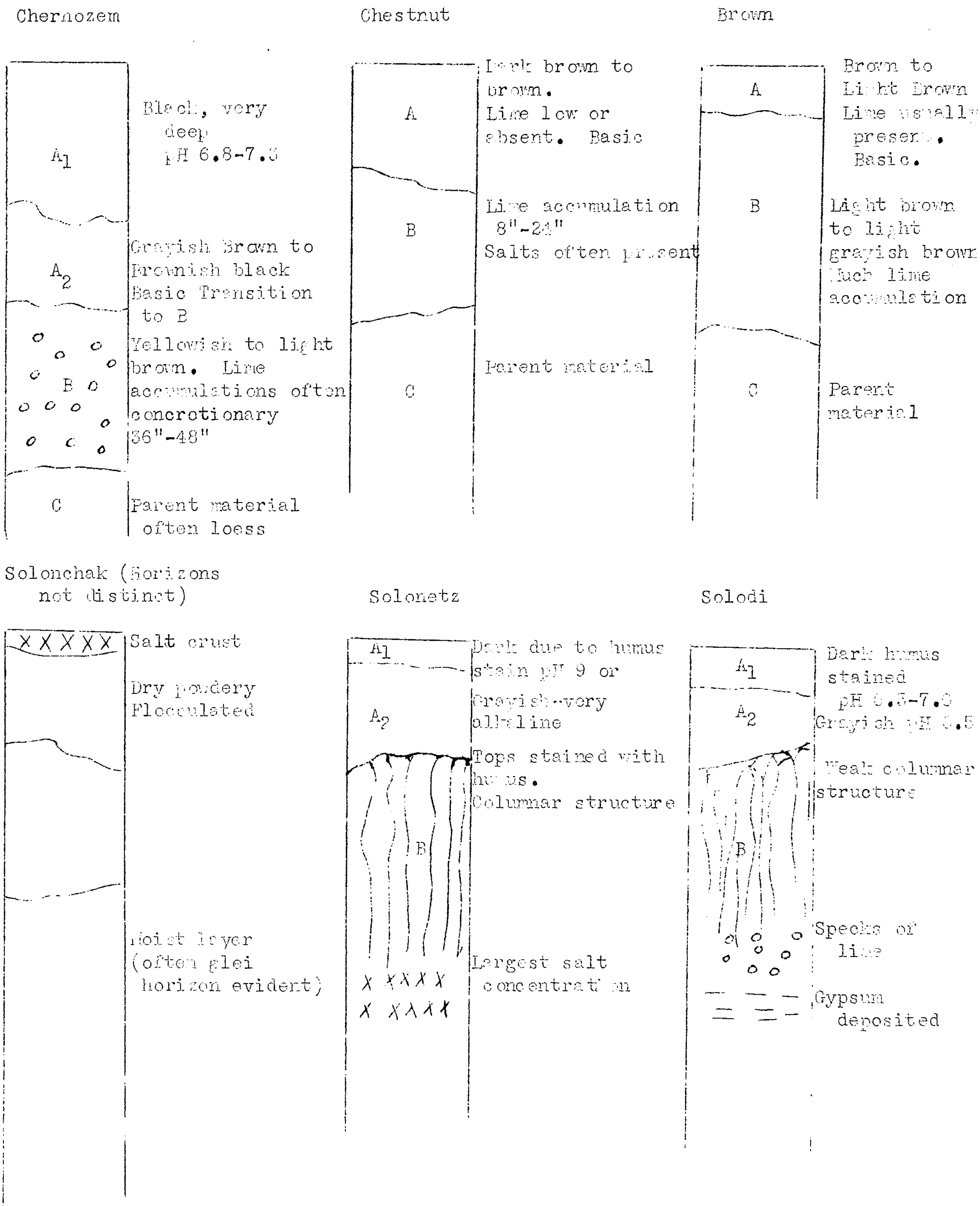


Table 1. General Characteristics of Soils and Their Environs

Zonal

Zonal soils	Profile	Native vegetation	Climate	Natural drainage	Soil-development processes
Podzol	A few inches of leaf mat and acid humus, a very thin dark gray A_1 horizon, a whitish-gray A_2 a few inches thick, a dark or coffee-brown B_1 horizon, and a yellowish-brown B_2. Strongly acid.	Coniferous, or mixed coniferous and deciduous forest.	Cool-temperate, except in certain places where the climate is temperate; humid.	Good to imperfect	Podzolization
Brown Podzolic	Leaf mat and acid humus over thin dark-gray A, and thin grayish-brown or yellowish-brown A_2 over brown B horizon which is only slightly heavier than surface soil. Solum seldom more than 24 inches thick.	Deciduous or mixed deciduous and coniferous forest.	Cool-temperate; humid. Effective moisture slightly less than in Podzol.	Good	Podzolization
Gray-Brown podzolic	Thin leaf litter over mild humus over dark-colored surface soil 2 to 4 inches thick over grayish-brown leached horizon over brown. heavy B horizon. Less acid than Podzols.	Mostly deciduous forest with mixture of conifers in places.	Temperate; humid	Good	Podzolization

Table 1 (cont.)

Zonal soils	Profile	Native vegetation	Climate	Natural drainage	Soil development processes
Red Podzolic	Thin organic layer over yellowish-brown or grayish-brown leached surface soil over deep-red B horizon. Parent material frequently reticulately mottled red, yellow, and gray; acid,	Deciduous forest with some conifers. (With cogonales--burned-over areas covered with cogon, tall coarse grasses.)	Warm-temperate to tropical; humid.	Good	Podzolization and laterization.
Prairie	Very dark-brown or grayish-brown soil grading through brown to lighter colored parent material at a depth of 2 to 5 feet.	Tall-grass prairie.	Temperate to cool-temperate, humid.	Good	Calcification with weak podzolization.
Laterite	Red-brown surface soil Red deep B horizon. Red or reticulately mottled parent material. Very deeply weathered.	Tropical selva and savannah vegetation. (Some cogonales)	Tropical; wet-dry. High to moderate rainfall.	Good externally. Good or excessive internally.	Laterization and a little podzolization.
Chernozem	Black or very dark grayish-brown friable soil to a depth ranging up to 3 or 4 feet grading through lighter color to whitish lime accumulation.	Tall- and mixed-grass prairie.	Temperate to cool; subhumid.	Good	Calcification

Table 1 continued

Zonal soils	Profile	Native vegetation	Climate	Natural drainage	Soil development processes
Chestnut	Dark-brown friable and platy soil over brown prismatic soil with lime accumulation at a depth of $1\frac{1}{2}$ to $4\frac{1}{2}$ feet.	Mixed tall- and short-grass prairie.	Temperate to cool; semiarid.	Good	Calcification
Brown	Brown soil grading into a whitish calcareous horizon 1 to 3 feet from surface.	Short-grass and bunch-grass prairie.	Temperate to cool; arid to semiarid.	Good	Calcification
Desert	Light gray or light brownish-gray, low in organic matter, closely underlain by calcareous material.	Scattered shrubby desert plants.	Temperate to cool; arid.	Good to imperfect.	Calcification

Intrazonal

Intrazonal soils	Profile	Native vegetation	Climate	Factors responsible for development	Natural drainage	Soil-development processes
Solonchak	Gray thin salty crust on surface, fine granular mulch just below, and grayish friable salty soil below. Salts may be centrated above or below.	Sparse growth of halophytic grasses, shrubs, and some trees.	Usually subhumid to arid. May be hot or cool.	Poor drainage with evaporation of capillary water. Salty accumulations.	Poor or imperfect	Salinization

Table 1 continued

Intrazonal soils	Profile	Native vegetation	Climate	Factors responsible for development	Natural drainage	Soil-development processes
Solonetz	Very thin to a few inches of friable surface soil underlain by dark, hard columnar layer, usually highly alkaline.	Halophytic plants and thin stand of others.	Usually subhumid to arid. May be hot or cool.	Improved drainage of a sodium Solonchak.	Imperfect	Solonization (desalinization and alkalization).
Solodi	Thin grayish-brown horizon of friable soil over whitish leached horizon underlain by dark-brown heavy horizon.	Mixed prairie or shrub.	Usually subhumid to semiarid. May be hot or cold.	Improved drainage and leaching of Solonetz.	Imperfect to good.	Solodization (dealkalization)
Alpine meadow	Dark-brown soil grading, at a depth of 1 or 2 feet, into grayish and rust soil, streaked and mottled.	Grasses, sedges, and flowering plants.	Cool-temperate to frigid (alpine)	Poor drainage and cold climate.	Poor	Gleization and some calcification.
Rendzina	Dark grayish-brown to black granular soil underlain by gray or yellowish, usually soft, calcareous material.	Usually grassy. Some broadleaved forest.	Cool to hot; humid to semiarid	High content of available lime carbonate in parent material.	Good	Calcification.
Planosols	Strongly leached surface soils over compact or cemented claypan or hardpan.	Grass or Forest	Cool to tropical; humid to subhumid.	Flat relief, imperfect drainage, and great age.	Imperfect or poor.	Podzolization, gleization. Also laterization in tropics

Some

Table 1 continued

Intrazonal soils	Profile	Native vegetation	Climate	Factors responsible for development	Natural drainage	Soil-development processes
Planosols (continued)	have normal A and B horizons above the clay-pan or hardpan--a secondary profile.					

Azonal areas	Profile	Vegetation	Climate	Drainage	Soil-development processes
Lithosols	Thin, stony surface soils--little or no illuviation. Stony parent materials.	Depends on climate.	All climates. Most characteristic of deserts; least so of humid Tropics.	A wide range, mostly good to excessive.	Those characteristic of the region. Little effect has been made.
Alluvial soils	Little profile development. Some organic matter accumulated. Stratified.	Depends on climate.	All climates except extremely frigid ones.	A wide range, mostly poor to good.	Those characteristic of the region. Little effect has been made.

Taken from "Soils and Men," 1938 Yearbook, pp. 996-1001.

Solodization

Continued leaching of a Solonetz results in the removal of sodium carbonate from the system. Hydrolysis of the adsorbed sodium occurs and it may be leached from the soil. As a result, a soil having a slightly acid surface soil is developed. The process is called solodization and the resulting soil is known as a "Solodi" or "degraded alkali" soil.

A Solodi has a thin, dark A_1 horizon underlain by a white, silty A_2 layer which is slightly acid. The B horizon shows a degraded or indistinct prismatic or columnar structure.

Solodi soils are rather uncommon, being found primarily in the Chernosem soil regions. (See Figure 7, Table 1).

It should be stated at this point that many transitional stages are found between the Solonchak, Solonetz, and Solodi and normal soils. For example, certain soils are found in western Colorado that have accumulations of black alkali salts, and yet do not have the structural characteristics of a true Solonetz. These soils are usually referred to as "slick spots" or "buffalo wallows."

Gleization

Gleization is the name given to the process causing the formation of "glei" horizons in soils. It is nothing more or less than the formation of bluish to grayish streaks in the mineral part of soil that is water-logged. Under such conditions, there is a lack of oxygen and iron is reduced to the ferrous state. Such salts are bluish. Where the water table fluctuates, giving rise to alternating oxidizing and reducing conditions, the glei horizon is characterized by mottlings of yellow, rusty brown, and bluish colors, especially along structural cracks and root channels.

Peat, Muck, Wiesenboden, and Alpine Meadow, as well as poorly drained alkali soils, may have glei horizons.

5. Classification of Soils. The first attempts at soil classification were generally made with a view to their practical significance, and it is only during comparatively recent years that the purely scientific approach has secured general recognition.

The earlier classification schemes were based on such features as adaptability to certain crops, texture or color of the soil itself, the nature of the parent material (geological) or upon some environmental factor. These differentiations were valid since they dealt with true soil differences, but were incomplete and served only local or limited purposes.

Of these schemes, the one advanced by the Russians, based largely on the climate, was the most satisfactory. In Russia, the vegetation closely followed the climatic changes, and rather sharp boundaries existed between plant associations, soil types, and climatic zones. In the United States a classification on the basis of climate, while superior in some respects to any on a geological basis, is still inadequate.

This recognition led to the abandonment of these schemes for the development of a strictly scientific classification based on the character of the soils themselves. Thus, the logical basis of soil classification is the complete soil profile.

The system of classification now used in the United States is arranged categorically in order to facilitate the study of the soil characteristics and the interpretation of their interrelationships.

The construction of a scheme of classification by categories is based on the recognition of all the soil characteristics. The number of characteristics taken into consideration in any category depends upon the comprehensiveness of the groups in the category.

Such a scheme of classification is somewhat similar to the schemes of grouping of plants and animals. The soil type corresponds to the plant unit. The higher categories in the soil scheme undertake to show the broader relationships of soil units just as those in the schemes for plant and animal classification do the same thing for plants and animals.

Beginning with the lowest category, soil type, soils are classified on the basis of progressively fewer characteristics into groups of progressively higher or more inclusive categories, namely, series, family, great soil group, suborder, and order. See Table 2 for the schematic classification of soils as used in the United States.

Soil Type

Type refers to a group of soils that is developed from a particular type of parent material, and similar as to profile characteristics. This category differs from the series in that the surface texture must be constant.

A phase of a soil type is recognized for the separation of soils within the type. Such soil types may differ in some minor characteristics. The latter should have special practical significance, such as relief or stoniness. For instance, a soil type such as sandy loam, and sandy loam, stony phase, may be found.

Series

A group of soils that is developed from a particular type of parent material, and similar as to profile characteristics, except for the texture of the surface soil, is called a series. These profile characteristics include structure, color, content of lime and salts, reaction, and humus content. Texture of the surface soil is the only variable allowable. Soil series are named after the town, county, river, or other well-known landmarks in which they were first identified. For instance, "Fort Collins," "Weld", and "Larimer" are all series names applied to soils in northern Colorado.

Family

This category includes groups, the units of which have certain profile characteristics in common, and which have developed through local rather than general environmental conditions. This category has not been as completely

TABLE 2 - CLASSIFICATION OF SOILS ON THE BASIS OF THEIR CHARACTERISTICS

Category VI	Category V	Category IV	Category III	Category II	Category I
Order	Sub-order	Great Soil Group	Family	Series	Type
Zonal — Pedocals	Cold zone	Tundra			
	Light-colored soils of arid regions	Red Desert Sierozem Brown Reddish Brown			
	Dark soils of semi-arid sub-humid & humid grass-lands	Chestnut Reddish Chest-nut Chernosem	(Example) Rosebud	Rosebud Keith	Rosebud fine sandy loam Keith silt loam
Zonal — Pedalfers	Forest-grass-land transi-tion	Prairie			
	Light-colored timbered regions	Podzol Gr. Br.-Podzol			
	Warm temper-ate to tropical forested region	Yellow podzolic Red podzolic Laterite			
Intrazonal	Halomorphic	Solonchak Solonetz Solodi			
	Hydromorphic	Weisenboden Alpine meadow Bog soils Planosols			
	Calomorphic	Rendzina			
Azonal	----------	Lithosols Recent alluvial Sands (dry)			

For complete discussion, see "Soils and Men", 1938 Yearbook of Agriculture, U.S.D.A. pp. 979-1001.

investigated and standardized as the others.

Great Soil Groups

Soils falling in this category all must have the same general sort of profile. They may differ from one another in parent material, relief, and age, but the internal profile characteristics must be similar. The soil groups falling in Category IV are listed in Table 2.

Suborder

This is a grouping of soils differentiated on the basis of the general composition of the resultant products of the soil-forming processes. The basis of classification in this category is primarily temperature. Terms used in this category to designate soils varying from the normal are: Halomorphic, Hydromorphic, and Calomorphic.

Halomorphic -- a suborder of intrazonal soils, the properties of which are determined by the presence of neutral or alkali salts, or both.

Hydromorphic -- a suborder of intrazonal soils owing their chief characteristic to impeded leaching and poor drainage.

Calomorphic -- a suborder of intrazonal soils owing their chief characteristics to the high content of calcium available to plants (frequently, but not always, in the form of soft calcium carbonate) in the parent material.

Order

On the basis of common characteristics, soils may be segregated into various broad groups. The degree of development of a soil as influenced by the soil-forming factors constitutes the basis of this category. Three orders are recognized.

Zonal soil (Normal) -- This includes any one of the great groups of soils having well-developed profile characteristics that reflect the influence of the active factors of soil formation -- climate and vegetation. This order is further divided into Pedocals and Pedalfers. The former soils have a horizon of accumulated lime in the soil profile, while the latter soils have no horizon of lime carbonate accumulation.

Intrazonal -- This group includes any of the great groups of soils with more or less well-developed profile characteristics that reflect the dominating influence of some local factor of relief, parent material, or age over the normal effect of the climate and vegetation. Intrazonal soils may be present in one or more of the Great Soil Groups.

Azonal -- This includes any group of soils without well-developed profile characteristics. Because of their youth or conditions of parent material or relief, the development of normal soil profile characteristics is prevented.

Figure 8 shows the distribution of soils in the United States, while Figure 9 gives a more detailed picture of the soils in Colorado.

6. Mountain Soils. The distribution of soil groups in mountain areas is governed by the principle of vertical zonation. For example, in passing from the plains of Colorado to the highest mountains, the following soil groups are traversed: Brown, Chestnut, Mountain Prairie, Gray-Brown Podzol and Podzol. In addition, Bog soils and Alpine Meadows are found.

The regularity of alternation in groups of soils in mountain regions is conditioned by the change in climate, and vegetation. Altitude, slope, exposure, and general landscape configuration are the topographic features that influence climate.

As altitude increases, the frequency of rains increases, and the amount of fall increases up to a certain point. Also, due to cleaner, drier, thinner air, great variations between night and day temperatures occur, and this is not favorable for rapid microbial decay of organic matter. The latter, combined with the fact that in Colorado an increase in elevation of about 1,000 feet decreases the mean summer temperature about 3 degrees F., allow for the accumulation of organic matter in such areas. Vegetative cover also changes with altitude, so that a succession of grass, forests, and finally Alpine vegetation occurs between the base and top of the mountain ranges.

Slope influences the genesis of soils due to effects of runoff, erosion, temperature, vegetation, etc. Rain runs off the steeper slopes, and increases the moisture content and leaching of the bottom soil. Slope exposure affects not only the type of vegetation but also the soil formed. Southern slopes are warmer and drier than northern slopes, having marked fluctuations in temperature and moisture. The northern slopes often show very highly developed soils. For instance, in one area above Estes Park, the soils on the northern slope of a ridge are true podzols, while those on the southern are Gray-Brown podzols.

Effective moisture percolation, total temperature values, exposure to sun rays and wind, and variation in flora are all potent factors in determining the type of soil that is formed in mountainous areas. Figure 10 shows a schematic arrangement of soils in Colorado from the Brown group through the Alpine Meadow.

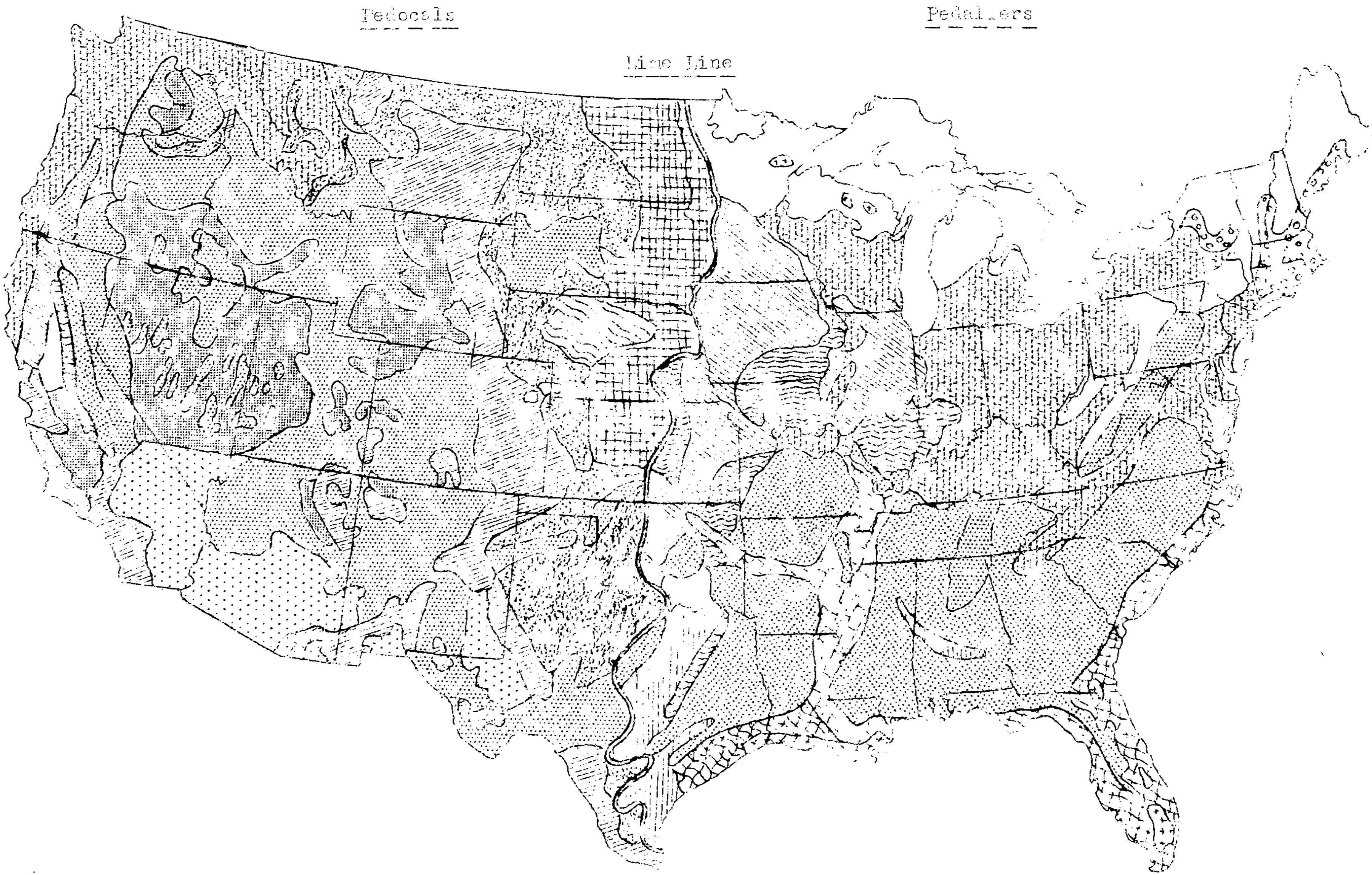
Brown soils are found in the Plains region in Colorado. They extend up to about the 5,000-foot, 15-inch rainfall lines, as a continuous body. Between about 5,000 and 7,500 feet elevation, and rainfall of 15 to 20 inches, Chestnut soils begin to appear along with the Brown soils. The locations of each are determined by local micro-relief and micro-climatic effects. Extending from 7,500 to 9,000 feet (20 to 30 inches precipitation) are found the Gray-Brown Podzolic and the Mountain Prairie soils. The former are formed under coniferous forests, while the latter are found under tall grass on moderately well-drained sloping lands. Often mucks and peats are found in the depressions in the valleys of this area. True podzol soils are found in the forested areas between 8,500 feet and timberline. The precipitation is greater than 30 to 40 inches. The best podzols are found on the northern slopes. Above timberline, Alpine vegetation appears. The soils of this area are usually shallow, usually quite moist, and high in preserved organic residues. Such soils are called Alpine Meadow soils.

7. Classification of Forest Humus Layers. Due to confusion in the classification of humus layers in forests, a system was proposed and adopted by

LEGEND

- Podzol Soils
- Brown Podzolic Soils
- Gray-Brown Podzolic Soils
- Prairie Soils
- Red and Yellow Podzolic Soils
- Chernozem Soils
- Chestnut Soils
- Brown Soils
- Sierozem Soils
- Red Desert Soils
- Planosols
- Lithosols and Shallow soils
- Rendzina Soils
- Wiesenboden, Ground Water Podzol and Half-Bog Soils
- Bog Soils
- Alluvial Soils
- Sands (Dry)

FIGURE 8. SOIL ASSOCIATIONS OF THE UNITED STATES



Adapted from 1938 Yearbook of Agriculture, Soils and Men

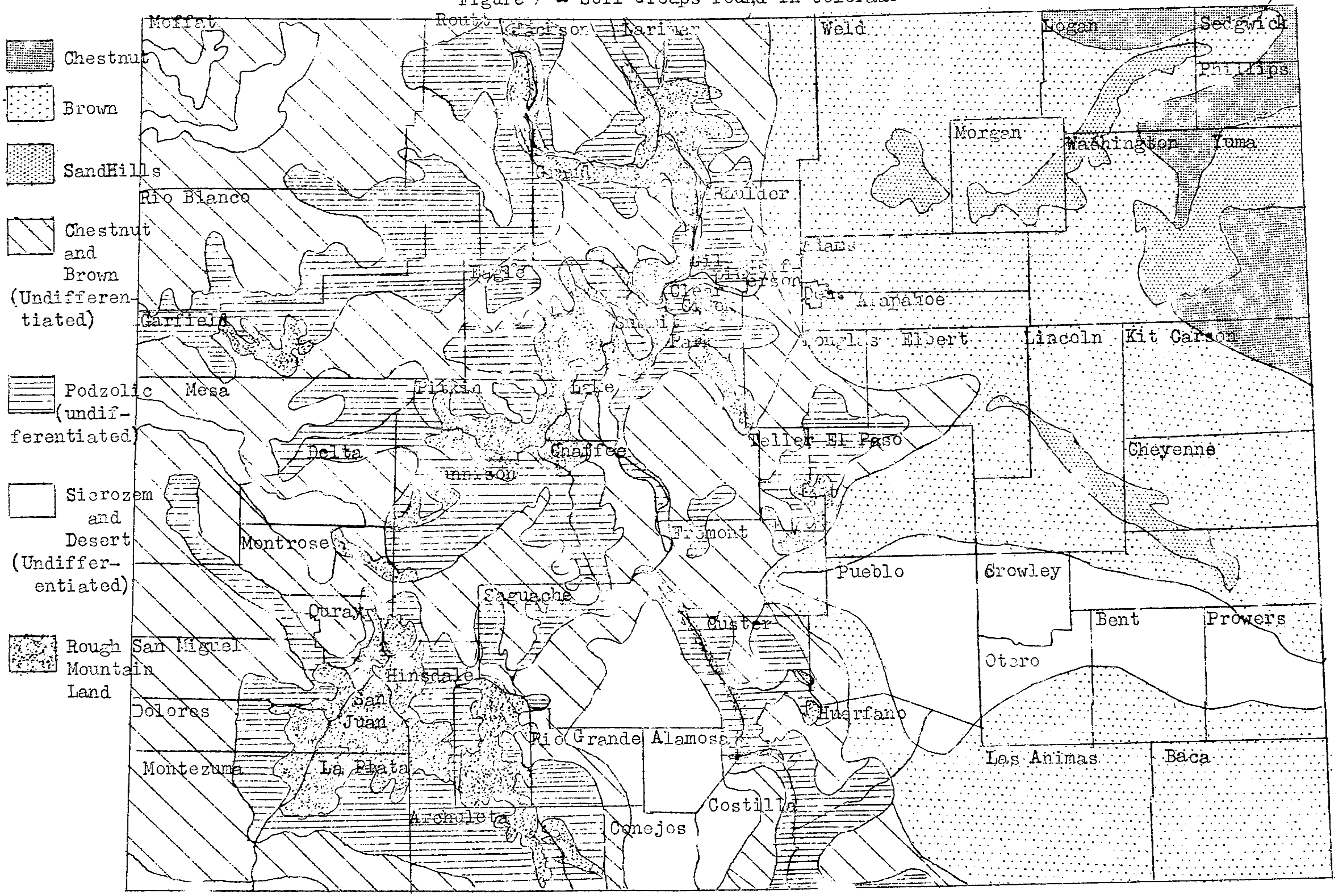


Figure 9 — Soil Groups found in Colorado

the International Congress of Soil Science (by Bornebusch and Heiberg). This classification was meant to apply to well-drained forest soils. The type names proposed are to be regarded only as examples of typical kinds of humus already recognized; other types will, undoubtedly, be added to these as more information is gained. The term "forest floor" is to be regarded as including the whole of the organic material on the soil surface and includes the recent litter.

The two kinds of humus layers recognized are "mull" and "mor". Mull is a mixture of organic matter and mineral soil, of crumbly or compact structure, with the transition to lower layers not sharp. Three forms are recognized.

Coarse mull -- Coarse grain structure, organic matter very conspicuously mixed with mineral soil. (Usually 5-20 percent organic content; exceptional cases even higher.)

Fine mull -- Fine grain structure, organic content high, usually over 50 percent.

Firm mull -- Dense, compact structure, usually low organic matter, often less than 5 percent.

Mor refers to organic layers practically unmixed with mineral soil, usually more or less mottled and compacted. Transition to mineral soil is always distinct. It is often composed of two layers -- F-layer (zone affermentation) and H-layer (humified layer). This type was formerly called "duff". Three kinds of mor are recognized.

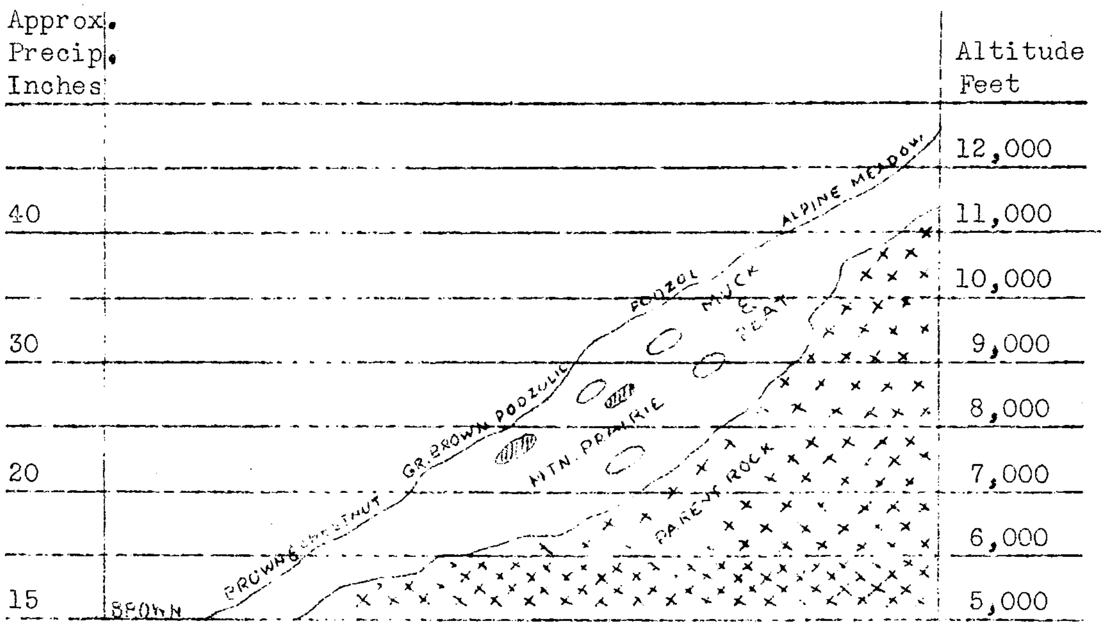
Granular mor -- H-layer pronounced and fine granular in structure; lower part somewhat compacted. In dry condition, very easily broken into fine powder when pressed by hand.

Greasy mor -- F-layer usually relatively little developed, often more or less fibrous. H-layer thick, compact, with a distinct greasy feel when wet, hard and brittle when dry.

Fibrous mor -- F-layer well developed. Both F-and H-layers fibrous, but not compact. Many plant remains visible also in H-layer.

Mor types predominate under the coniferous forests of the Rocky Mountain region. Mulls are occasionally found under open stands and under aspens.

Figure 10. Vertical Zonation of Soils in Colorado Mountains.



Review Questions

1. Review the changes that occur as (1) rocks are converted into parent material, and (a) as soil material is converted into soil.
2. List the five general factors influencing soil formation (equation).
3. Prepare a statement concerning the effects of each factor on soil formation.
4. What common soil materials have contributed to the formation of soils in the great plains region?
5. In what states or general areas in the U.S. are the following parent materials of importance: loess, lake deposits, crystalline rocks, glacial accumulations, sandstone and shales, limestone, marine deposits?
6. Why is there a close relation between rainfall evaporation lines (effective precipitation) and soil boundaries?
7. Where are the highest rainfall belts in the U.S.? The lowest? How about Colorado?
8. How does the following types of vegetation differ in content of bases (ash): grass, coniferous, deciduous? What effect does base content have on soil formation?
9. Compare the effect on soil development of forest vegetation and grass.
10. Explain how a "mature" and a "young" soil may lie side by side in the same environment.
11. In what general regions in the United States are the following vegetative types found: short grass, tall grass, hardwoods, coniferous, desert shrub, mixed forest?
12. Where in Colorado are the following vegetative types found: short grass, shrub, coniferous?
13. Under what conditions are "normal" soil profiles developed?
14. What is the "A_0" horizon? Distinguish between the L.F. and H. horizons.
15. Explain "soil development" in terms of the "age" factor.
16. Explain the process of podzolization. Give the general conditions necessary for the process to occur, and the great soil groups influenced by this process.
17. Be able to draw a Podzol and a Gray-Brown Podzolic profile. Label them completely.
18. Define or explain: bleicherde, ortstein, orterde, solum, truncated profile, "inherited" characteristic, "acquired" characteristic.
19. Describe the process of laterization, and give the conditions necessary for the process to occur.
20. Where are laterite soils found? How has laterization influenced the formation of the red and yellow podzolic soils of the U.S.?
21. Describe the process of calcification, and give the conditions necessary for this process to occur.
22. Be able to draw a chernosem, brown, and chestnut soil profile. Label completely. (How does a Prairie soil differ from a chernosem?)
23. Why is there little or no eluviation of colloids and humus in soils formed by calcification?
24. Distinguish between the processes of salinization, solonization, and solodization. How do the profiles differ?
25. What salts are present in saline soils? Alkaline soils?
26. Define or explain: Solonchak, solonetz, solodi, saline, alkaline, gleization, glei horizon.
27. The complete soil profile is the basis of soil classification. Why?
28. Give the present system of classifying soils in the United States. Explain the basis for each stage.
29. Distinguish between the following and explain each; soil (1) type, (2) phase, (3) series, (4) family, (5) group.

30. What is a lithsol? Planosol? Bog soil? Weisenboden? Rendzina?
31. Explain: halomorphic, hydromorphic, calormorphic soils; pedalfer, pedocal, zonal soil, intrazonal soil, azonal soil.
32. Be able to sketch a map of the United States showing the location of all the great soil groups.
33. What great soil groups are found in Colorado? Where found? General vegetative types?
34. What soil groups are found between eastern Colorado plains and the highest mountain regions. Explain.
35. Where are peat soils found in Colorado?
36. Distinguish between mor (duff) and mull. Describe three subtypes of each.
37. Where in Colorado are mor layers found? Mulls?
38. Given: Fort Collins clay loam. Trace it through the six categories of the classification.
39. What is a soil survey? Purpose?
40. Give five uses of a soil survey.
41. Be able to discuss the principal soil management problems involved in the handling of each of the great soil groups.

The following references, from which the greater part of the above material was taken, are cited for further reading.

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