THE ORIGIN OF OHIO SOILS

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The soils of any region owe their character primarily to the conditions of environment under which they have developed. Just as in the biological world, also in rock weathering and in soil development, the key note is adaptation to environment. When rock material is exposed at the surface changes take place with the production of compounds which are more stable under that environment. Moreover, any change in environment will result in changes toward compounds which are more stable under the new conditions.

Factors of major importance in soil development include parent material, climate, vegetation, topography and drainage, and age. This is sometimes expressed in the form of an equation(1)[1]:

$$\text{Soil} = \gamma \text{ (climate, vegetation, relief, age, parent rock)}$$

If soil material stays in place for a sufficient time for the environment to be impressed on it, the result is expressed or shown in the development of layers or horizons differing in characteristics, such as color, texture, structure, consistency, etc., from the surface downward. This succession of horizons makes up the *soil profile.*

For information concerning soil material—parent material—we turn to our geologists. First, the bedrock of Ohio is everywhere sedimentary. West of a line drawn from Sandusky through Columbus the underlying rock is largely limestone, to the east sandstone and shale predominates. Actually much of the sandstone is in reality a siltstone—a very fine grained sandstone which weathers to silt.

Throughout about two-thirds of the state the surface materials are glacial in origin. The local character of the drift is shown in that 75 per cent or more is made up of material transported less than 25 miles. In western Ohio then, there is glacial limestone material, in northeastern and east central areas glacial sandstone and shale material. In northwestern Ohio and a narrow belt bordering Lake Erie in northeastern Ohio, the soil material is largely glacio-lacustrine in origin.

Beyond the glacial border in southern and southeastern Ohio the soil material is predominantly residual in origin. Its character depends on the nature of the local rocks—limestone and calcareous shale in Adams County in southern Ohio, and sandstone and shale in southeastern counties, except locally where limestone may be important; elsewhere red clay shale.

Climate is of first importance as an environmental factor in soil development. The most important climatic factors are rainfall and temperature, along with humidity and length of the frost free period.

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[1]Numbers in parentheses refer to literature cited at end of paper.

Of special importance in soil development is the amount of water actually percolating through the soil. The actual soil climate will be conditioned by the slope of the land and the vegetative cover. The total rainfall, then is not an important factor, rather the effective moisture after losses by runoff and evaporation have been taken into account.

Transeau (2) in 1905 suggested the rainfall-evaporation ratio as an index to precipitation efficiency. Although records of evaporation were very limited, the concept was fundamental, and has been very helpful in evaluating climates. In 1935 Transeau stated that evaporation data was still very meager.

In the absence of data on evaporation, several attempts have been made to evaluate this factor from temperature records. Lang (3) in Germany in 1915 suggested the Rain Factor (annual precipitation in millimeters divided by mean annual temperature in degrees centigrade). The fundamental concept, that evaporation varies directly with mean annual temperature, does not agree with facts. Meyer (4), also in Germany, in 1926 used the N-S-Q value—the N-S quotient, that is precipitation in millimeters divided by the saturation deficit. The latter (S) was calculated from the vapor pressure for the mean annual temperature and the relative humidity. (V. P. $\times$ [100—relative humidity]).

Thornthwaite (5) has devised a new classification of climates, based on precipitation effectiveness and temperature efficiency. The sum of $\frac{P}{E}$ and $\frac{T}{H}$ ratios for each month gives a $\frac{P}{E}$ index and a $\frac{T}{E}$ index for the year. The value E is calculated from the temperature, by use of an equation derived from values for stations with evaporation data.

Based on any of these considerations, Ohio is in an intermediate climatic area, but not far from the borders of the cool humid area to the north, the warm humid area on the south and the prairie area on the west. Although there is not much variation in climate within the bounds of the state, it would not take much change in either temperatures or rainfall to shift the area into one of the other climatic belts. In fact, the vegetation shows relics of all three of the neighboring climatic belts. Some of the climatic relationships are summarized in Table I.

The vegetation factor will be discussed in detail by Dr. Transeau. Suffice to say here that most of our soils have developed under a dense mixed hardwood forest. The possible effects of past changes in climate and in vegation have not been evaluated.

In addition to the factors of climate, vegetation, drainage and relief in soil development, age is an important factor. Time alone is not the only factor, the rate of change must be considered. For the mature soil to develop the material must stay in place for a long period of time. But there are different degrees of maturity. For example, the soils derived from the Illinoian drift have leached to a depth of 8 to 10 feet, those from Lake Wisconsin drift to only 2 or 3 feet—this being a result of the difference in age. The drift of both areas is highly calcareous.

As a result of the action of these various forces on the soil material, profound changes have taken place, varying in intensity from the surface downward. The soil forming processes include the following:

1. The decomposition of the minerals of the soil material.
2. The accumulation of organic matter on the surface and within the upper soil horizons.
3. The leaching of soluble products of decomposition of both mineral and organic matter.
4. The translocation downward of soil material from some layers and the deposition in others.
5. The formation of new compounds by decomposition and by recombination.
6. The development of structure with the production of aggregates that break along rather definite lines.

TABLE I.

PRECIPITATION EFFICIENCY

	Ohio Gray-brown Podzolic Soils	Podzol Soils	Red and Yellow Soils	Prairie Soils
$\frac{P}{E}$ (Transeau)	80–100	130–150	100–130	60– 80
$\frac{R}{T}$ (Lang)	80– 90	110	65– 80	70– 90
N-S-Q (Meyer)	300–350	500–800	300–450	300–400
$\frac{P}{E}$ (Thornthwaite)	64–128	64–128	64–128	48– 64
$\frac{T}{E}$ (Thornthwaite)	48– 64	32– 48	64–128	32–128
Mean Annual Temp.	54°F. (12°C.)	40°F. (4°C.)	68°F. (20°C.)	42°F.–56°F.

In the investigation of soils their character, or morphology, is carefully studied in the field. Representative samples of the horizons are subjected to examination in the laboratory, their physical and chemical composition are studied. However, a chemical analysis must be supplemented by mineralogical studies to give an idea of the mineral composition of the material. A study of the mineral composition of the coarser fractions of the soil gives an idea of the unweathered, resistant minerals and is an aid in tracing the origin back to the parent material. Only within the last few years has it been possible to identify the products of weathering—the clay minerals (6). The methods for identification include the X-ray diffraction method, dehydration studies and others, along with chemical analysis of the clay minerals.

Studies have revealed the presence of a number of hydrated aluminous silicates. Only in tropical or subtropical regions does the silica-aluminium ratio approach the 2 to 1 value required for kaolinite—$Al_2O_3 . 2SiO_2 . 2H_2O$—the commonly suggested product of weathering of feldspars. Assuming a ratio in the unweathered mineral of 6 to 1 as in orthoclase—$K_2O . Al_2O_3 . 6SiO_2$—the common clay minerals in soils of humid temperate regions have a ratio of 3 or 5 to 1. These minerals have been identified as montmorillonite, beidellite, etc. They have high base exchange capacity, high water absorption capacity and high plasticity. Another group of minerals, variously called illite, glimmerton, X-mineral and hydrous mica, are somewhat similar to muscovite in composition, but contains less potash and more water by hydration along with silica and alumina.

In contrast to these are the clay minerals in lateritic soils of the subtropics in which the silica-alumina ratio is approximately 2 to 1 as in kaolinite. However, the common mineral has been identified as halloysite, which contains more water of hydration than kaolinite. They are characterized by low base exchange capacity and low plasticity. In laterite—a red soil of the tropics—the common mineral is a hydrated aluminum oxide. This whole field of the mineral character of clay minerals is a new one, the future should yield an abundance of important information.

Given sufficient time the net result of all of this is the development of a soil profile with layers or horizons with definite and distinctive characteristics. In case these processes go on unimpeded, either by erosion as on steep land, or by a high water table, as on very gently sloping or level land, the nature of the soil developed will be primarily an expression of the effects of climate and vegetation—external forces in soil development. These soils can be called mature soils or normal soils. Such soils, owing their characteristics primarily to climatic and biological (chiefly vegetation) agencies, occur in zones or areas corresponding closely with climatic and vegetation zones and hence, have been called *zonal* soils.

These are the naturally well drained soils of the state (7)—some are derived from materials high in lime, as in western Ohio, some from materials low in lime and some from noncalcareous materials as in northeastern Ohio. These are the best wheat soils of the State.

These features are characteristic of the great soil group, the gray-brown podzolic soils, and are distinct from the podzol soils to the north, the red and yellow soils of the south and the dark-colored prairie soils to the west. This soil zone extends from the prairie in Indiana and Illinois to the Atlantic seaboard. Throughout the whole area the main characteristics of the normal mature soil are essentially alike.

In association with the zonal (normal or mature soil) are soils which because of poor drainage, or steep topography have not developed the normal mature profile. These are called *intrazonal* soils, in that their chief characteristics are the result of some internal factor or condition. In one case adequate artificial drainage may be a first essential for their utilization; in the other case the erosion hazard may be a limiting factor.

In addition these soils are those which for one reason or another, show little or no profile development. Recent alluvial deposits are a good example. These are called *azonal* soils.

The typical zonal soil of Ohio, irrespective of soil material, has the following features:

1. A thin layer of leaf litter.
2. A dark grayish-brown layer, 2—3 inches thick.
3. A grayish-brown to brown soil.
4. A light yellowish-brown subsurface about the same in texture as the surface soil.
5. A yellowish-brown upper subsoil somewhat heavier than the surface soil, 10 to 15 inches thick, with a definite blocky structure.
6. The more or less unweathered soil material.

In association with the light-colored well-drained soils, and derived from similar soil material, are the poorly drained intrazonal soils. Those that are dark in color, with adequate artificial drainage prove to be the best corn soils of the state. The poorly drained light-colored soils, the gray soils, are characterized by a tight impervious subsoil. They are the most difficult to drain, the most acid, and are the lowest in productivity, of any of the soils in the association. To these gray poorly drained soils the group name of *planosols* has been given.

At the other extreme are the soils developed on steep slopes where geological erosion has kept pace with soil development. Here there is only a thin layer of soil over partially decomposed rock. Under such conditions the erosion hazard is the limiting factor in land use. Such soils are called *lithosols.*

Soils derived from similar soil materials, whose chief differences are the result of differences in topography and drainage are grouped in a *soil catena,* and the name of the best drained soil in the group is used for the name of the catena: For example, the Miami catena includes the soils derived from glacial limestone drift. The soils of a catena may be closely associated together in an area, on a farm, and even in one field.

As a result of the interaction of the forces of soil development, a variety of soils have been produced. Each has its distinctive characteristics. In its utilization in the production of crops useful to man each soil has its particular adaptations, its distinctive problems in soil conservation. Although the soils of the region naturally are of only moderate natural fertility, they are very responsive to good management and under the favorable climate form the basis of a stable agriculture.

On the level areas drainage is a problem. In the lake plain areas of northwestern Ohio, the heavy clay soils show a marked deterioration in structure with a resulting lowering in crop yields. In northeastern Ohio, the problem of soil acidity is uppermost. Better drainage on the smoother areas, erosion control on the rolling areas near the glacial border, are essential in an adequate land use program.

In southeastern Ohio the problem of erosion control is dominant in land use planning. Many steeply sloping areas, not adapted for rotation crops, can best be utilized for permanent pasture or for forests. The deeply leached soils of southwestern Ohio present a multiplicity of problems. The extensive gray soils on the broad flats are difficult to drain, are highly acid, and are very low in productivity.

Thus each area with its distinctive soil association presents its special problem in soil utilization. Situated as we are on the eastern edge of the corn belt, and at the western border of the Appalachian Plateau, we have a variety of problems in soil conservation.

LITERATURE CITED

(1) Soils and Men, U. S. D. A. Yearbook of Agriculture, pp. 948–1001. 1938.

(2) **Transeau, E. N.** Forest Centers in Eastern United States. Amer. Nat., 39: 875–889, 1905.

(3) **Lang, R.** Investigation of an exact classification of the soil from the climatic and geological point of view. Inter. Mitt. fur Bodenkunde, 5: 312–346. 1915.

(4) **Meyer, A.** Concerning several relationships between climate and soil in Europe. Chemie der Erde, 2: 209–347. 1926.

(5) **Thornthwaite, C. W.** Climates of North America. Geog. Review, 21: 633–655. 1931.

(6) **Alexander, L. T., Hendricks, S. B.,** and **Nelson, R. A.** Minerals present in soil colloids. II. Estimation in some representative soils. Soil Science, 48: 273–279. 1939.

(7) **Conrey, G. W.,** and **Burrage, E. M.** A key to the soils of Ohio. Ohio Agricultural Experiment Station Spec. Circ. No. 44. Revised Edition. 1938.