THE GENETIC CLASSIFICATION OF SOILS.

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All classifications of soils yet proposed may be divided into two groups: (*a*) *scientific classifications* which are based on the natural characteristic of the soil, and (*b*) "*applied*" *classifications* which are based on the suitability of soils for certain crops, or on the revenue that may be derived from them.

According to the features on which the study of soils is based, the scientific classifications are divided into

(1) *the geologico-petrographical*, in which the soils are grouped according to the geologico-petrographical character of the rocks which make up the soil. (The classification of Fallou, Mayer and others.)

(2) *the chemical* or *chemico-petro-graphical*, according to the main chemical features of the soil (Knop).

(3) *the physical*, according to the mechanical composition and the physical characteristics derived from it. (Thaer, Schübler, the classification adopted by the Bureau of Soils for the investigation of soils in the United States of America.)

(4) *the combined classifications*, by which soils are divided into groups, for example according to their mechanical composition, and subdivided according to either their chemical composition or other features. (Senft, Kosticheff, and others.)

(5) *the genetic*, by which soils are divided into groups depending on their origin and development. (Prof. Docuchaiev, Prof. Hilgard, Prof. Ramman (in part), and Prof. Sibirtzev.)

In the present article I cannot touch on the applied classifications, or on the first four groups of the scientific classification; I shall, therefore, confine myself solely to the last, i.e. the genetic classification of Prof. Sibirtzev, which is the classification of Prof. Docuchaiev enlarged and improved. Prof. Hilgard's work in the classification of

soils is confined to the fundamental groups (Sedentary, Colluvial and Alluvial soils).

The scientific, but not the applied definition of soil, must emphasize its characteristic peculiarities as a natural substance which originated in the weathering of rocks, and which is the field of the life activity of immense quantities of animal and plant organisms. *By the word soil,* therefore, *we mean the loose surface strata of the earth's crust in which general dynamic processes* (weathering, erosion, etc.) *have taken place, and are taking place in conjunction with chemico-biological processes* (such as the action of plants and animals, their decomposition, the activity of microorganisms, the accumulation of humus, and the like).

Soil, according to the expression used by Prof. Docuchaiev, is a mirror which exactly reflects the mutual activities of the above-mentioned factors in its development (i.e. rocks, organisms, physico-geographical conditions, and the age of the country). Soil is the result of the factors enumerated, and if these factors are equal then the resultant soils will be equal, and *vice versa.*

Keeping in mind this fundamental statement, it is absolutely necessary, in forming a scientific classification of soils, to fix those combinations of the factors of development which cause the process of soil formation to take a certain direction, and which, generally speaking, will finally lead to equal results. We know, for instance, that only weathering of rocks can thoroughly obliterate the difference among them. This equalization of those products of the weathering of the different rocks will be still greater when the organisms which settle in them work in the same direction.

Thus it is possible, for instance, to determine what combination of factors of development will have as a result the so-called Black soil (tchernozem of Russia, and the black soil of the prairies in the United States). The most important characteristic of these soils is the increase of humus, under the influence of a temperate climate, grassy steppe plants, and lime. Under such conditions we always find black soil, as, for example, in Southern Russia, Hungary, N. and S. Dakota, Nebraska, Kansas and some other central States of North America.

If we have glacial material as the formative strata in a moderately cold climate with a large amount of rainfall, and tree vegetation, then the development of sour humus is the most characteristic feature of the soil formation. The solution of humic acids removes the greater part of the soluble matters of the soil from the upper layer, and deposits them in the lower, and as a consequence the percentage of insoluble

material (silica) increases in the upper strata. Soils of this character are not only to be found in the glacial deposits of the northern parts of European Russia, but also cover the plains of Denmark, Northern and Central Germany, Holland, and France. One may infer that this kind of soils is to be found in North America (Canada), just as it is found in the Asiatic possessions of Russia (Siberia).

The study of the typical combinations of the factors of soil formation enabled Prof. Sibirtzev to establish the following types, which include every possible variety of soil.

I. *Laterite soils.* These are developed in humid tropical climates. The characteristic feature of their development is a rapid disintegration of the formative rocks (granite and others) owing to excessive heat and moisture. Hence the salts of potash, soda, calcium, and magnesium are removed, and the percentage of iron and alumina salts in the remaining mass increases. Soils of this description are best studied in India, Ceylon, Japan, China, in parts of Russia (on the south-eastern shore of the Black Sea), and may also be found in Central America, and in Africa.

II. *Wind-blown Loess soils.* These are developed under the influence of a dry and warm climate, i.e. in the central parts of large continents (e.g. Asia). The characteristic feature of disintegration of rocks under such conditions is the formation of dust. This dust is carried by the wind great distances, and, being deposited, forms a mass of loess which is sometimes a thousand feet deep, according to Richthofen's "China." These soils are distinguished by an abundance of carbonates of calcium and magnesium, and a small amount of humus. They cover immense areas of Asia (China, Turkestan, Persia), and of Northern Africa and America.

III. *Soils of the dry Steppe.* The characteristic climatic feature is a small amount of rainfall (10—15 in.) which occurs as a rule during the summer, xerophile plants, and an alkaline character of the formative strata. To this class belong the soils of the desert and of the Cactus and Artemisian Steppe. They contain a small amount of humus, and the process of washing-out is very slow, owing to the small amount of rainfall. They are found in South-eastern Europe, Russia, Siberia, in parts of Spain (desiertos), western States of America (Utah, Nevada, Arizona, California) and in South America.

IV. *Black soils* (*Tchernozem*). They cover generally the grassy steppe or prairies of the temperate zone. The subsoil is mostly fine-grained, wind-blown and glacial loess, which contains a large amount

of carbonate of lime. Topography, plains; climate, continental, dry, with from 18—20 in. of rainfall, mostly in summer. The characteristic feature of this soil is an increase of neutral humus up to 15 per cent. and even more. The character of these soils may vary within wide limits, according to the conditions of a particular locality.

The Black soils are best studied in European Russia where they represent one of the best and most important soil regions. They are further found in Western Siberia, Hungary (pusstas), Bulgaria and Galicia. In the States of N. and S. Dakota, Nebraska, Kansas, Arkansas, Indiana, Oklahoma, Mississippi, and Texas the Black soil is quite analogous to the tchernozem of Southern Russia. The same soil is also found in Argentina (Buenos Ayres, Santa Fe, etc.).

V. *Gray soils* (forest-steppe soils) are developed under conditions very similar to those of the Black soils, but instead of grasses we generally find forests of deciduous trees. They have practically the same formative strata as the Black soil, but a greater amount of rainfall makes them more leached, and these conditions make possible the growth of forests instead of grass. Besides the smaller quantity of humus, which is shown by the lighter colour (gray), as compared with the tchernozem, the characteristic features of these soils are a smaller amount of calcium and magnesium, and in general of all nutritive substances which can be washed away. They are found in strips along the northern boundary of the tchernozem in Russia, Western Europe, and in North America on the boundary between prairies and forests.

VI. *Peat and ashy (Podzol) soils.* These originate in cold-temperate or cold climates, with a large amount of rainfall and little evaporation. The formative strata generally consist of glacial deposits (loam, clay, and sand). The vegetation consists for the most part of forests, heather, meadow and swamp plants. The most characteristic feature of the Podzol, owing to the development of humic acids by decomposition of organic matter, is the dissolution and removal of soluble parts of silicates (Ca, Mg, K, Na, Fe, Al), and an increase in the percentage of insoluble silica. This silica gives the soil its characteristic whiteness and ash-like texture, from which it receives its Russian name. The amount of humus in these soils is very small (2—3 per cent.), and a considerable part of it is soluble in water. These soils differ widely in character. They cover the northern parts of Europe, Russia, Siberia, and all plains of North-western Europe, and may be expected in Canada.

VII. *Fenland (Tundra) soils.* These are developed from different

kinds of formative strata which were slightly decomposed under the influence of scanty fen plants and an extremely cold climate with a large amount of rainfall. The subsoil is almost constantly frozen. Owing to the small amount of vegetation (mosses, lichens), and the insufficiency of heat, which in turn hinders the decomposition of organic matter, these soils are poor in humus. They are found in the Arctic regions of Europe, Asia, and America.

The seven fundamental groups of *'zonal' soils* just enumerated are spread over the surface of large continents in zones which coincide with the physico-geographical zones of those continents. The most typical expression of these zones of soils is found on the Eurasian continent; it must, however, be understood that this zonal distribution of soils is merely a rough scheme. Some factors in soil formation undergo sharp changes within comparatively short distances, and therefore we never find zonal soils covering a continent in an uninterrupted belt. In this scheme the soils enumerated are spread over the Eurasian continent beginning with laterite soils in the extreme south, and gradually reaching the tundra (fen) soils of the north.

Since the climatic factors at work will also vary with the height above sea-level we may observe as in the Caucasus a vertical zonality of soils corresponding to the lateral zonality previously described. In all these zones also certain interzonal soils are sure to occur, which owe their peculiarities to special conditions of topography alone. Such are swamp and alkali soils and the calcareous soils resulting from the decomposition of limestone. Incomplete soils of coarse materials, such as are found in mountainous regions, and alluvial soils are also common to all the zones. Furthermore within the limits of any one zone various intermediate stages are possible which depend upon the degree of intensity in the factors in their development. Such soils constitute the six (VIII—XIII) interzonal types enumerated by Sibirtzev.

If he keeps in mind this main idea in the study of the soils of a given locality, the problem of the investigator will resolve itself first of all into the determination of the factors of soil formation. This determination will show him the most important types of soils. The next step will be a more detailed study of the dynamics of the process of soil formation, i.e. how some factors of the development of soils are reflected in their character: what is the influence of the duration of the soil formation, climate, topography, plant and animal organisms, etc. When this combination between soils and the factors of their formation has become clear in the mind of the investigator, he will

know that under certain physico-geographical conditions, and from certain rocks, only certain soils can be expected, and under other combinations, other soils.

I have endeavoured to state the most important features of the genetic classification of soils which have been applied to the best classification which up to the present time has been devised for the soils of European Russia (that of Prof. Sibirtzev). In spite of its seeming complexity, its fundamental feature is the general statement that soil is the product of the conditions of its development, and that the peculiarities of soils are closely interrelated.

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