GENESIS OF SOILS AND FACTORS OF THE SOIL FORMATION

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Summary

Soil formation is a complicated natural process of soil origination from mountain rock under effects of the soil-forming factors in natural or anthropogenic ecosystems of the Earth. Soil formation is a global biospheric process, and as a result of its manifestation a soil attains a number of typical features, those are absent in the soil-forming rock and distinguish the soil from other components of the biosphere. The soil-forming process takes place under the influence of certain soil-forming factors. Five factors of the soil formation are distinguished: climate, relief, mountain rocks, organisms, and time. Each of these has its influence upon the soil formation, and this process is impossible without contribution of one of them. In this sense, all these factors are equivalent and irreplaceable.

In the course of its formation every soil passes through a number of successive stages whose direction, duration, and intensity are determined by a concrete complex of soil-forming factors in each particular point on the Earth: the stage of initial soil formation, the stage of development, the stage of equilibrium, and the stage of evolution.

The whole process of soil formation can be separated into component processes of a lower level, which are called elementary processes of soil formation. The diversity of natural conditions in different landscapes results in manifestation of very varied

combinations of soil formation. Diversity of these combinations is determined by both, evidence or absence of one or another process under certain natural conditions, and the intensity of each of these processes. This extremely wide diversity of complexes of the soil-forming processes leads finally to a large diversity of soils on the land.

1. Soil Formation is a Global Natural Process

Genesis (origin) of soils is a formation of them from mountain rocks and their further (following) development under influence of soil-forming factors in natural and anthropogenic ecosystems of the Earth.

Soil formation is a global biospheric process, and as a result of its manifestation a soil attains a number of characteristic properties, which are absent in the soil-forming rock and those distinguish soil from all other components of the biosphere. Among the most essential features of this type is the presence in the soil of one or another quantity of specific organic substance that is soil humus. It is absent in the soil-forming rock, and it appears as a result of the soil-forming process. Accumulation of humus in the soil is associated with one of the most important biophylic elements which is the nitrogen that is also absent in a soil-forming rock. As a result of soil formation the soil gains specific structure. A soil profile is a system of horizons, which are more or less parallel to the Earth's surface, and formation of those is determined by the soil formation.

2. Factors of Soil Formation

A soil-forming process runs its course under influence of factors of soil formation, which are natural conditions external to the soil. Founder of the soil science (pedology) Vasily V. Dokuchaev and his followers recognize (distinguish) five factors of soil formation: climate, relief, mountain rocks, and time. Each of these factors exerts its influence upon soil formation, and this process is impossible without any of them. In this sense, all these factors are equivalent and irreplaceable.

The climatic factor determines provision of soil formation with moisture (atmospheric precipitation) and energy (the solar radiation). Exactly these conditions in a great part determine the intensity of processes, running in soil. The known rule of Vant-Hoff, according to which the temperature rise by 10 degrees increases the reaction rate by 2-4 times, is certainly correct for the soil processes. Favorable hydrothermal conditions have influence upon communities of vegetable and animal organisms, increasing their productivity that finally also has effect on the intensity of soil formation.

Relief exerts some action on the soil formation by both, directly, causing movement of soil masses along slopes as a result of erosion-accumulation processes, and indirectly, redistributing heat and moisture by its elements, and thus forming original climatic conditions.

A soil-forming rock, which is sometimes called the mother (parent) one, is that basis, on which and from which a soil is formed. The mineral part in an overwhelming majority of soils constitutes more than 90%, and more frequently 95% of the soil mass. That is precisely why the original rock determines chemical, mineralogic, and granulometric

composition of soils. A rock does largely determine the rate of soil formation. Thus, under identity of other conditions, this rate will be significantly greater on loess sediments, rather than on sands, and the same on alluvium of basalts soils will be formed considerably faster than on alluvium of granites.

Functions of organisms in the soil formation are extensive and various. Soil formation is a biogenic process, and it starts since from the moment of settling of living organisms on massive-crystalline and sedimentary rocks. Organisms are the only source of organic substance, which serves as a material for formation of soil humus. Another important function of organisms is based on the ability of living substance for selective absorption of elements. Owing to this fundamental property, the organisms to a large degree determine chemical composition of soils.

3. Stages of Soil Formation

In the course of soil formation, each soil passes through a number of successive stages, whose direction, duration, and intensity are determined by a concrete complex of soil-forming factors at each concrete point on the Earth (Rode, 1984).

The initial stage soil formation is characterized by those properties of a soil body, which are typical for developed soils, still have not been formed. The thickness of the soil profile is not large (normally it amounts to several centimeters), and the profile itself is weakly differentiated into horizons, and their quantity is not big. Accumulation of biophylic elements is weakly expressed.

The initial soil formation is changed by a stage of the soil development, which runs with increasing intensity, penetrating more and more large thickness of the soil-forming rock. This stage goes on up to formation of mature soil with typical profile and complex of properties. By the end of the stage of (the soil) development the soil comes into a state of equilibrium with a complex of soil-forming factors. This corresponds to the beginning of the third stage, i.e. a stage of equilibrium, the duration of which can be indefinitely long. During the stage of equilibrium, more or less permanent dynamic equilibrium between a soil and its environment, i.e. between existing soil-forming factors, is sustained.

At some stage of a soil existence, the stage of equilibrium is changed with that of the soil evolution that happens through self-development of ecosystem, one component of which is the soil. It can also proceed (take place) under the influence of change of one or several factors of soil formation, i.e. climate, vegetation, character of soil moistening, or it can be the result of irrigation or the soil drainage, etc. The stage of evolution can be compared with the stage of soil development. Its result is a new stage of equilibrium, and a new soil with new profile and new complex of soil properties corresponds to that stage. Formation of a meadow soil from a swamp after drainage of a territory can be an example of a soil evolution. In the case of evolution, a soil is formed not directly from a soil-forming rock, but from a preceding soil. Several such evolutional changes of soil formation can take place on the same substratum, and exactly such complicated history of development is typical for majority of soils on the Earth. Similar soils are called polygenic (polygenetic) ones. It is often possible to meet in the profile of such soils

some relict features which are inherited from the past (previous) stages and not related to a present-day stage of soil formation.

4. Processes of Soil Formation

In the course of soil formation the chemical composition of a soil-forming rock changes. Some substances are carried (washed) out of its thickness, included into (enveloped with) a soil formation, while others are accumulated. In the course of soil formation, accumulation of a substance is accounted for by inflow of organic substance of plant and animal residues into a soil as well as from the hydrosphere (easily soluble salts, gyps, carbonates of alkaline and alkali-earth metals, compounds of iron, earth silicon, coming from groundwater) and the atmosphere (dust particles of different sizes and composition, compounds, being contained in the atmospheric precipitation). Outflow of substance from soil can take place with downward and lateral water flows in the soil, removal of soil particles from its surface with water and wind flows. A ratio between the substance accumulation and removal determines the balance of soil formation.

On the Earth's surface, a soil-forming process takes its course under the influence of a great diversity of combinations of the soil-forming factors that result in a diversity of the soil formation types and respective soils. At the same time, the same processes are repeated in different soils, and they are essentially of the same quality, but different by their intensities and in details of their manifestation. As an example of such processes can be accumulation of humus, occurring in all soils, though at different qualitative and quantitative levels. Another example can be the process of desalting, i.e. an outflow of easily soluble salts with downward water flows from the profile of an initially salted soil. It is important to underline that these processes are specific soil processes.

Such processes, common for different types of soil formation, are termed as elementary soil-forming processes (ESP). These processes are complicated in their nature, and the notion "elementary" should not be interpreted as 'simple'. At present, the list of these processes can not be considered a final one as well as the methodology and criteria for separation of the soil-forming processes.

At presen, several tens of elementary soil-forming processes are identified. All their variety is divided into several groups according to the balance of substances, determined by these processes, and to qualitative composition of compounds, which are results of manifestation of these processes (Rozanov, 2004).

1. *Biogenic-accumulative ESP*. A group of processes, leading to accumulation of organic (and other) substances in the upper part of a soil profile with direct participation of organisms. This group includes such processes as forming of humus, accumulation of forest litter (floor), peat formation and others.

2. *Hydrogenic-accumulative ESP*. Group of processes, leading to accumulation of substances, coming to a soil profile from ground waters. This group includes such processes, as salinization (accumulation of easily soluble salts), carbon enrichment (carbonization) (accumulation of calcium carbonate at its deposition from mineralized ground waters), metallization (hydrogenic accumulation of oxides and hydroxides of

iron), and others.

3. *Metamorphic ESP*. Group of processes of transformation of the soil minerals at a site, i.e. without outflow or income of them from other parts of a soil profile. These are such processes as siallitization (intrasoil weathering of minerals with formation of secondary clay, represented by finely dispersed stratified aluminosilicates, fersiallitization (a process of accumulation of oxides and hydroxides of iron against a background of siallitization), gleization (a process of transformation of a mineral mass under influence of regenerative situation, caused by long waterlogging of the soil), and others.

4. *Eluvial ESP*. A group of processes of destruction or transformation of a soil material with subsequent outflow (evacuation) of products of destruction or transformation outside limits of an eluvial horizon. This group includes lixiviation (leaching) (outflow of calcium carbonate or easily soluble salts with downward water flows), podsolization (a partial destruction of soil minerals by acid soil solutions and evacuation of products of this destruction with downward water flows), lessivage (peptization and evacuation) of finely dispersed soil particles in their undestroyed state with downward moisture, and others.

5. *Illuvial-accumulative ESP*. A group of processes of accumulation in the lower part of a soil profile of a substance, evacuated (removed) from an eluvial horizon. This group includes such processes as argillo-illuvial process (a process of illuvial accumulation of silty particles, evacuated (removed) from an eluvial horizon at the lessivage), Al-Fe-humus illuvial process (a process of illuvial accumulation of oxides and hydroxides of iron and aluminum together with humus), and others.

6. *Pedoturbative (Pedoturbitive) ESP*. A group of processes of intermixing of a soil mass under the influence of different factors, i.e. both natural and anthropogenic. Examples of processes from this group can be cryoturbation (a process of mechanic unregulated movement (displacement) of soil masses at irregular freezing and melting of the soil), and bioturbation (intermixing of soil by animals, inhabiting it).

7. *Destructive ESP*. A group of processes, leading to physical destruction of soil. In particular, erosion (a process of destruction of soil due to action of running water or wind) relates to such processes.

5. Genesis of Soils under Different Ecologic Conditions

A great diversity of natural conditions on the land surface of the globe is responsible for a wide diversity of combination of the soil-forming factors. This, in its turn, results in manifestation of very different combinations of processes of soil formation. Variety of these combinations is determined by both, presence or absence of one or another process under certain natural conditions, and by intensity of each of these processes. This extremely wide diversity of complexes of the soil-forming processes results finally in a wide diversity of soils on the land. Below is the description of genesis of main groups of soils, which are the most representative in the soil cover of the globe.

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Bibliography

Bridges, E.M. (1997) *World soils*. 3rd edition. Cambridge, UK, Cambridge University Press. [Characteristics of soils on the globe are presented, and regularities of their distribution are described].

Ponomareva V.V., Plotnikova T.A., (1980) *Humus and soil formation*, Leningrad, Nauka. [The book explains characteristics of the humus-forming processes and features of composition and features of humus in main soil types].

Rode A.A., (1984) *Genesis of soils and present-day processes of soil formation*, Moscow, Nauka. [Basic propositions on evolution concept in the soil science (pedology) are formulated in this book].

Rozanov B.G., (2004) *Morphology of soils*, Moscow, Publ. Akademichesky proekt. [Unique analysis of morphologic features of the soil had been performed in relation to a character of its formation, composition, and properties].

Samoilova E.M., (1981) *Meadow soils of European forest-steppes*, Publ of Moscow State University. [Hydromorphic soils of the forest-steppe zone are characterized, features of formation of them, their composition and properties, related to increased wetting are shown].

Vasilevskaya V.D., (1980) *Soil formation in tundras of Middle Siberia*, Moscow, Nauka. [The most important features of soil formation and soils, being formed under conditions of cryogenesis are characterized in the monograph by examples of tundras of Central Siberia, i.e. a vast territory, extending from the Yenisei river in the west to the Lena in the east.

FAO, (1998) *World Reference Base for Soil Resources*, Rome. [A guidebook for pedologists, used as a basis for creation of international soil classification and common language for specialists, using information on soils. The book contains rules for classification and separation of reference soil groups as well as brief description of world soils].

Biographical sketch

Alexander Sergeevich Vladychensky (born in 1948) is a Doctor of Biological Sciences, professor. In 1971, he had been graduated from the Lomonosov Moscow State University (MSU) as a pedologist-agrochemist. A citizen of Russia, he is now one of leading Russian scientists in the field of soil genesis. His Doctor's thesis (1994) was devoted to a problem of soil formation in mountain regions. He works in the MSU Faculty of Soil Sciences since 1974, and since 1999 he is a head of Department of General Soil Science. Vice-president of the Dokuchaev society of pedologists and chairman of Sub-commission on the forest soil science. He is author of over 160 papers in scientific journals. He is a chairman of Sub-commission on Forest Soil Science.