Investigations of 'Sigmond on Chernozem Soils

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Professor ALEXIUS A. J. DE 'SIGMOND's investigations on soils are familiar to soil scientists all over the world and it is also well-known that he acquired a profound knowledge and experience of almost the whole range of soil science and agrochemistry. 'SIGMOND's papers and monographies, published on the various soils types, represent a considerable part of his many-sided scientific activity. In his book "The Principles of Soil Science" [4] and in the monography "Characteristics of the main soil types of Hungary. Part 1. Chernozems or black (dark-brown) steppe soils" [5] 'SIGMOND presented a detailed description of these soils, characterized their morphological, physical, chemical and biological properties, discussed their genetic and dynamic characteristics, their formation processes, analysed the role of natural and human factors in their development and gave a scheme for their detailed classification. In the present paper 'SIGMOND's conception on chernozem soils are briefly discussed and interpreted from the viewpoint of modern soil science and the scientific results of more recent investigations on chernozem soils are summarized.

Black (dark-brown) steppe soils

The original Russian term "chernozem", which has been generally accepted, accurately defines a special soil type but the more or less synonymous terms, like "black earth" or "black soil" are not always used in a strictly identical sense. Therefore the detailed comparative analysis of the Russian chernozems and the Hungarian black (dark-brown) steppe soils, given by 'SIGMOND and KOTZMANN in their monography [5], had and still has special scientific importance.

Seven profiles were selected for their study from the various parts of the Hungarian Plain: Mezőhegyes, Gyula, Békéscsaba, Bajmok, Csorvás, Homokos (South Hungary), Adony (Transdanubia).

In 'SIGMOND's general soil system the chernozems (or the steppe soils) are classified into Soil Order 11: Calcium soils. For the exact identification of the studied soils detailed analyses were carried out. According to the analytical data the sum of exchangeable cations (S-value) was rather high in the top horizons and gradually decreased with depth. It means that the effect of weathering is the most intensive in the upper layers (this is true of humus formation, as well). In these soils the alkali salts are leached out of the upper horizon; $CaCO_3$ is also washed down more or less into the deeper layers; nevertheless in the soil absorption complex (according to 'SIGMOND "humus zeoliths complex", formed from decomposed silicates and humus substances) sufficient exchangeable calcium is present to ensure stability and to prevent migration within the soil profile and accumulation in a certain horizon. The immobility of sesquioxides in chernozem soils is clearly indicated by the data of their analysis. Because the absorption complex of the studied soils is saturated mostly with Ca^{2+} these soils can be classified as calcium soils. The exchangeable Ca^{2+} content gradually decreases in the soil profile with depth while the exchangeable Mg^{+} (and at places K^{+}) content increases. Exchangeable Na^{+} (if any) occurs only in the deeper layers of these soils.

For the identification of chernozems (black or dark-brown steppe soils) their natural environment and their morphological characteristics have special importance. The depth of humus layer is generally considerable in these soils (for instance it was about 100 cm in the Mezőhegyes profile) and forms a gradual (sometimes diffuse) boundary to the yellow loess parent material. The soil has an excellent, well-developed and rather stable crumbly structure and the water economy is favourable within the whole profile. The surface is never waterlogged. In the C horizon (loess) there are numerous krotovinas and lime concretions. The relief is nearly flat generally with gently undulating microrelief.

During the joint Conference of Commission II (Soil Chemistry) and the Alkali Subcommission of the International Society of Soil Science (Hungary 1929), the Mezőhegyes profile was demonstrated to the participants and according to the opinion of Russian soil scientists it could be defined as chernozem on the basis of its morphological characteristics. 'SIGMOND shared their opinion and classified this soil into the order: Calcium soils, and into the main type: Black (dark-brown) steppe soils. At the same time he pointed out that the humus content of this soil was much lower than that of the typical Russian chernozems and in this respect the studied soils were more similar to chestnut steppe soils. The main cause of the lower humus content is that in Hungary these soils have been used as arable land for centuries, while the Russian chernozems are covered with natural steppe vegetation (or were broken only some decades ago). As a consequence of long-term agricultural utilization the N content is lower in the Hungarian "chernozems" and because of the relatively rapid decomposition of plant residues their C : N ratio is also low. The results of the aqueous extract analysis, in accordance with the exchangeable cation composition, indicate that in the deeper horizons there is a certain Na^{+} accumulation both in the liquid and solid phases of the soil. Salinity and alkalinity in the deeper layers occur in the Russian "southern chernozems". 'SIGMOND summarized the dynamic characteristics of the black (dark-brown) steppe soils formed on loess in the Hungarian Plain, as follows:

"1. Both the soluble silica and sesquioxides are immobile and their migration within the soil profile is practically negligible.

2. There is a downward movement of alkali earth carbonates, the $CaCO_3$ and $MgCO_3$ are more or less washed down into the lower horizons. Their molecular ratio is nearly constant. There are no carbonate and sulphate accumulation horizons in the upper 150 cm of the soil profile.

3. Humus substances are stable and accumulate in the upper layers. The organic matter content varied between 2.5 and 5 percent. At the beginning the decomposition of organic matter is rather intensive but afterwards it is restrained by the Ca^{2+} saturation and the slightly alkaline reaction of the soil.

4. Among the exchangeable cations Ca^{2+} is predominant, the quantities of exchangeable Mg^{2+} and Na^{+} increase with depth. Similar tendency can be observed in the ion composition of soil solution."

'SIGMOND's conception on chernozem soils was verified by the latest results in soil genesis researches and it was modified to a certain extent only in the most recent classification systems [1, 6, 7, 11, 13]. The new results indicated not only the similarities but also the differences between the Hungarian dark-brown steppe soils and the Russian southern chernozems. Salinity and alkalinity in the deeper horizons are caused by hydrological conditions in Hungary [8, 9, 10]. In the Hungarian chernozems salt accumulation horizons generally can not be observed at the lower boundary of the wetting front, as a result of the leaching effect of precipitation.

Salt accumulation occurs only at places where an impermeable layer, or a relatively high water table limits the downward movement of water in the soil profile. In the mycelial lowland chernozems and meadow chernozems hydromorphic features can be observed in the soil profile and sometimes considerable salinity can be measured (without a well expressed salt maximum) in the layers near the water table.

According to 'SIGMOND's classification all Hungarian chernozems would belong to one subtype of the present genetic soil classification system (lowland chernozems, salty in deeper layers), because he took samples only from this subtype and did not investigate the chernozem soils on the Transdanubian [Mezőföld, Tolna and Bácska (southern part of the region between the rivers Danube and Tisza)] loess plateaus, where the groundwater had not influenced the soil formation processes.

'SIGMOND's conception on chernozem soils has been somewhat revised and enlarged on the basis of our detailed soil genetic studies, and the conclusion has been drawn that in the Danube-Valley countries (including Hungary) and in the western parts of the USSR (Precaucasia, Moldavia, Ukraine) mycelial or lime-coated chernozems have formed on the well-drained river terraces [12]. In these soils the leaching and accumulation processes are in equilibrium and the surface of the well-developed structural elements (macro- and microaggregates) is covered by pseudo-mycelia: a white $CaCO_3$ coating.

Brown steppe soils

On these soils — according to 'SIGMOND — moderate humidity results in a less abundant natural grassland vegetation than on the black (dark-brown) steppe soils, consequently their organic matter content is lower. For instance in the brown steppe soils in the surroundings of Szeged (Southern Hungary) the humus content varies between 1 and 4.5 percent. The characteristic brown color of these soils emanates from humus substances and not from sesquioxides like in other brown soils (brown earths, brown forest soils). Consequently there exist only moderate weathering processes in the brown steppe soils, the weathering products are mostly immobile and do not migrate within the soil profile. A slight increase of the Ca-saturated soil absorption complex can be observed in the top horizon. Results of the aqueous extract analysis indicate negligible salinity in these soil profiles.

Ballenegger [2] described some Hungarian light brown steppe soils and classified them as a subtype of brown steppe soils. According to 'Sigmond these soils were originally steppe soils and degraded into brown forest soils under forest vegetation. After deforestation, just the opposite process took place and regraded steppe soils developed. Consequently this soil formation process cannot be used for the characterization of primary light brown steppe soils.

Our most recent soil geographical studies indicate that the occurrence of environmental factors leading to the formation of brown steppe soils is rather limited in Hungary (spots on the southern slopes of undulating surfaces with drier microclimate and less soil moisture) therefore the Hungarian chernozems cannot be classified as brown or light-brown steppe soils.

Degraded steppe soils

'Sigmond defined the degraded steppe soils as a main type of hydrogen soils (Soil Order 10).

Degradation is a kind of soil metamorphosis. In the degradation of calcium soils, the calcium soils, change into hydrogen soils due to increasing humidity. The term "degradation" implies a decrease in value also from the agricultural point of view as a result of the destruction of the saturated soil absorption complex. This destruction is caused by a permanent change in the dynamic system of the calcium soil, thus producing a new main type. The transformation is gradual, lasting until the calcium soil has lost all its original characteristics and the whole profile has been converted into a typical forest or wet meadow soil.

The degradation processes were first studied in Russia on the northern boundary of the chernozem zone where the latter adjoins the southern boundary of the forest zone. Forests are continually encroaching on the steppes. The transition is gradual and leads to the development of a steppe-forest zone in which the steppe vegetation is gradually being replaced by forest vegetation. Under the influence of this new vegetation-type the local soil climate becomes constantly and uniformly more humid and soil degradation processes begin: eluvial A, illuvial B and C horizons develop; carbonates are leached from the upper layers; desaturation; $Ca^{2+} \rightarrow H^{+}$ occurs, acidity increases, etc. 'Sigmond described such phenomena in a Hajdúdorog chernozem profile on the Debrecen loess plateau.

Soil degradation is clearly indicated by unfavourable changes in the soil's physical and water properties. The well-developed, good and stable crumbly structure of chernozems becomes gradually more dense and is transformed into plate-like, or small prismatic structure in the eluvial A horizon, and "nutty" or "pyramidal" structure in the illuvial B horizon. These physical changes are accompanied by definite changes in the soil's biological properties.

'Sigmond — in accordance with Selke — was of the opinion that degradation may be caused not only by forest vegetation, but also by an increase in humidity. More probably, the hydromorphic, heavy-textured meadow soils of the Hungarian Lowland were formed from black steppe soils by degradation under the influence of a special peat vegetation. The lower classification units of *degraded calcium soils* were distinguished by 'SIGMOND according to the degree of degradation and a special subtype was defined as "steppe soils degraded by an excess of groundwater".

'SIGMOND considerably enriched our knowledge on soil degradation processes and his conception was widely used in the Hungarian soil classification and soil mapping practice. In the semi-detailed soil survey, the term "degraded steppe soils" referred to various soils having black or dark-brown color and leached (non-calcareous) humus horizon.

The present conception on degraded steppe soils is somewhat different. These soils occur in the regions between forest and chernozems or meadow and chernozems.

It is not probable, however, that in the continuously subsiding Hungarian Lowland chernozem development was the primary soil forming process and that it was transformed into meadow soil formation under the influence of peat vegetation. In Hungary degradation means only the leaching of the calcareous parent material during the primary forest soil or meadow soil formation.

Due to the changes in natural soil forming factors (tectonic activity, erosion, climatic changes, etc.) and to human activity (flood control, deforestation, intensive farming, etc.) chernozem processes began as secondary soil formation.

In addition to this general trend another type of degradation was observed in the surroundings of Battonya (Southern part of the region beyond the Tisza river). In this region, under the influence of the high water table (1—2 m), the hydromorphic "meadow-process" can be observed on chernozems, and meadow chernozems (at places salty in deeper horizons) have developed. The high water table resulted in serious deteriorations of agriculture and after exceptionally humid years (1939—1942) large areas were waterlogged [3] in this territory, while in the surrounding Berettyó—Körös and Tisza—Maros region (which is situated 10—20 m lower!) practically no ponded water appeared on the soil surface and the water table rised but slightly. The main cause of this anomalia was the peculiar geological character of the Southern Transtisza region. In this alluvial fan the texture of fluviatile deposits becomes finer with the distance from the detrital cone and the horizontal groundwater flow becomes slower. After a longer humid period the horizontal groundwater flow from the coarse-textured aquifers to these heavy-textured alluvial deposits is limited by their relatively low hydraulic conductivity and a part of the filtrating groundwater cannot penetrate into these layers, which results in a gradual accumulation of groundwater, in a rise of the water table in the coarse-textured geological horizons. At some places the water table rises up to the surface and influences considerably the soil forming processes. It has happened in the Battonya region where the river Maros, during the holocene period, silted up its pleistocene riverbed cut into the loess-plateau and the raised water level of the river caused a significant rise of the water table in the relatively coarser textured higher alluvial fan around Battonya.

Secondary and tertiary calcium soils

To these soil types belong, for the most part, the transitional Hungarian chernozems. According to 'SIGMOND there are cases in which human invention does not — or only transitionally — transform the dynamic equilibrium of the soil and influences the original soil type only slightly. There are soils, however, in which the anthropogenic factor results in radical changes (H-soil → → Ca-soil, Na-soil → Ca-soil, etc.) and the dynamic characteristics of soils become entirely different due to human intervention. Naturally in this latter case the new soils cannot be included in their original categories. 'SIGMOND grouped this "man affected" calcium soils into the group "secondary and tertiary calcium soils". They are calcium soils formed on various primary soil types (various parent materials) and their physical, chemical, biological and dynamic properties are determined — and so can be characterized — by the absolute and relative predominance of Ca^{2+} ions in both the liquid and solid phases of the soil.

Contrary to 'SIGMOND's generalized opinion (primary process: chernozem formation; secondary processes: degradation of steppe soils; forest soil and meadow soil formation; tertiary process: regradation of steppe soils) our physico-geographical and soil-geographical studies have revealed that first of all forest soil and meadow soil formation can be regarded as primary processes and the transitional soil types [chernozem-brown forest soils, meadow chernozems, alluvial (terrace) chernozems] developed from these primary soil types as secondary formations under the influence of changes in the environmental factors and/or due to the effect of human activity.

Classification of steppe soils

In 'SIGMOND's general soil system chernozems are classified into the Order 11 — Calcium soils, the degraded chernozems into the Order 10 — Hydrogen soils. (Main type 5: degraded calcium soils). The main characteristic of Ca-soils is the Ca-saturated soil absorption complex. Within Soil Order 11 eight main types were distinguished, as follows:

1. Black (dark-brown) steppe soils (Tshernosems)
2. "Prairie" soils
3. Rendzinas
4. Tropical and sub-tropical black earths (black soils)
5. Brown steppe soils
6. Grey steppe soils
7. Secondary and tertiary calcium soils
8. Calvero soils (light chestnut, dry forest soils).

Of these main types the black steppe soils are of the greatest importance in the Hungarian Plain. 'SIGMOND distinguished only two genetic horizons in the chernozem (steppe soil) profiles: the upper humus layer (A horizon) and the parent material (C horizon). Eight subtypes of chernozems were distinguished according to the degree of leaching, $CaCO_3$ distribution, appearance of Na^+ in the soil profile and parent material. In stages VI, VII and VIII the local soil varieties are characterized in detail by their environmental conditions (orographical, hydrographical, climatic conditions, parent material), physical properties and plant nutrient content.

Besides the black steppe soils secondary and tertiary calcium soils also cover relatively large areas in Hungary. To this main type belong 4 subtypes as follows:

1. Tertiary or regraded steppe soils
2. Calcium soils artificially formed from peat soils (Holland, Hungary, etc.)
3. Calcium soils formed by liming and deep ploughing from soils originally acid but not turf or peat soils
4. Calcium soils formed by suitable reclamation from alkali soils.

Among the secondary and tertiary soils, the soils formed under the influence of ancient human activities (deforestation, flood-control, water regulation, etc.) and soils only slightly and recently affected by man's intervention (intensive farming, irrigation, fertilization, tillage, etc.) have to be distinguished. Especially the latter, so-called "man-made" soils should be the subject of further investigations.

'SIGMOND's conception on chernozem soils based on detailed morphological studies, laboratory analyses and on vast experience provided a firm basis for further research.

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