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Complex pedologic analysis of the Hungarian erubáz soils with special reference to their clay-mineral composition

PhD Theses

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Introduction, objectives

One of the most ignored and less studied soil types in our soil science is the so called *erubáz* or *fekete nyirok (~black wet soil)*. In the Hungarian genetic soil classification system, the erubáz is a special soil developed on volcanic rocks. The main reason for its negligence is the fact that this soil occurs in small patches dispersed in hilly regions of the country, which are outside the scope of the agriculture. Because of its inferior role in agricultural mass-production and small areal extent, only the forestries and some vineyerds are interested in studying the erubáz soils.

In the 1950's STEFANOVITS P. – differently from his predecessors – dealt also with soil-types, which were not of primary agricultural importance, so that his investigations included the forest soils, too. Consequently, the erubáz was included in his genetic soil-classification system as an independent soil type. Since then very few works have been done and scarce data have been assembled about these soils.

Objective of my PhD work was the detailed field- and laboratory inspection of this scarcely known soil type. Special emphasise was put on its clay content and clay-mineral composition as main characteristics of the erubáz soils were explained by these parameters. In the Hungarian genetic soil classification system only the erubáz soil type exists, no sub-types and varieties are identified. However, it became obvious in the early stage of my study that this soil type is far from being as uniform, as it is suggested by the classical definition. Main goal of my research is to work out a classification-system for the different varieties of the erubáz soil by means of detailed description of soil profiles. Large scale geomorphologic mapping was done in the High-Börzsöny study area to examine the sub-types and varieties, to learn about their geomorphologic position and to reveal their areal extent and appearance. Analysis of the mechanical composition of the erubáz soils, measurement of the real clay-content is difficult, primarily as a consequence of the high humus-content. Therefore I elaborated a special soil-preparation method, which is suitable for this peculiar soil type, and for other soils of high humus-content, too.

In the international WRB system (World Reference Base for Soil Resources) the volcanic soils are assembled within the group of the Andolols. In this study I carried out the WRB classification of the erubáz-soils to find out if these could be included in the Andosols group or they belong to another WRB category.

Methods

Location and description of the profiles, sampling

Determination of the location of the soil profiles and sampling occurred in accordance with the principles of soil-mapping. In the Börzsöny study area a data point-network was planned on the basis of geological and topographic maps. During the mapping 38 soil profiles and 115 soil core samplings were done. A Thales Mobile Mapper GPS was utilised to locate the points on the field. The FAO (1990) standard was used for the description of the 15 processed profiles.

Standard and specific laboratory analyses

Laboratory analysis of the soil samples was carried out in the laboratory of the HAS Geographical Research Institute, in accordance with the certified standards. The following measurements were completed on the samples: pH value ($pH_{[H2O]}$; $pH_{[KCl]}$), $CaCO_3$, inorganic and organic carbon, humus content, bulk density. The natrium-dithionite Fe_d- és Al_d-, the ammonium-oxalate Al_o-, Fe_o-, Si_o-, and the natrium-pyrophosphate Al_p-, Fe_p-contents were determined using atom-adsorption spectrophotometer. Colour of the samples was defined using the MUNSELL colour scale in dry and wet states.

Study of the mechanical composition

Study of the mechanical composition was preceded by a methodological experiment where samples from the Ah_1 horizons of the most humic profiles developed on basalt, basalt piroclastite and andesite were analysed. These samples were investigated three times applying four different preparation methods. (1) traditional Na-pyrophosphate; (2) using hydrogene-peroxide; (3) hydrogene-peroxide treatment with 6 hours shaking in water-bath and (4) hydrogene-peroxide treatment with 6 hours shaking in water-bath followed by the traditional Na-pyrophosphate treatment for the perfect dispergation. As a result of my experiment, the (4) hydrogene-peroxide treatment with 6 hours shaking in water-bath followed by the traditional Na-pyrophosphate treatment was applied on the samples analyzed in my thesis. After disintegration of the aggregates the mechanical composition of the suspension was determined using Fritsch Analysette Microtech 22 laser diffraction particle size analyzer.

Mineralogical and clay-mineralogical analysis of the soils

Mineralogical and clay-mineralogical analysis of the soils occurred with X-ray diffraction (XRD) method in the HAS Geochemical Research Institute by means of a PHILIPS PW 1710 equipment. XRD analyses were done on random-powdered samples of the entire soil materials and the semi-quantitative mineral composition of the soils was estimated according to the methodology of NÁRAY-SZABÓ–PÉTER–KÁLMÁN (NÁRAY-SZABÓ I.–PÉTER É. 1964; PÉTER É.–KÁLMÁN A. 1964) modified by BÁRDOSSY GY. (1966, 1980). For the determination of the swelling clay minerals the samples were saturated by ethylene-glykol. For the separation of the chlorite and for the revelation of the OH interlayering, the samples were heated to 350 and 500 °C. Separation of the smectite-vermiculite occurred on the basis of the Mg-saturated samples treated by glycerine. For the separation of the montmorillonite and beidellite the Green-Kelly-test was utilized. The layer-charge of the smectites was estimated via K-saturation. Determination of the clay-mineral types took place in accordance with the methods summarized by THOREZ, J. (1976), and DIXON, J. B. (1989), and on the basis of the data on minerals present in the studied the soils.

Clay-mineral analysis of three samples (Badacsony, Tihany, Tokaj) were carried out in the Martin Luther University of Halle, in the laboratory of the „Institut für Bodenkunde und Pflanzenernährung", using a Siemens D5005 X-ray diffraction equipment.

Study of soil-biological activity of the erubáz soils in natural (open ground) conditions

Total soil-biological activity and dynamism of the decomposition of the cellulose were studied in each season in both the black and the brown erubáz soils, in accordance with the slightly modified UNGER-cellulose-test. The measurements were carried out between March 2007 and 2008 in the Börzsöny study area next to the B101 and B102 profiles.

Measurement of soil-moisture

Soil-moisture was determined using two automatic soil-moisture measuring equipments located next to the locations of the UNGER-test. 2-2 Eijkelkamp soil moisture block were connected to these equipments, which were placed 1 and 20 cm below the surface. The measurements were carried out between March 2007 and 2008.

Data processing and presentation of the results

Processing of pedological data and classification of the profiles into the World Reference Base for Soil Resources occurred on basis of the WRB (2006) reference book. Digital database was compiled using the Microsoft Excel software. The SPSS program was used for the statistic analysis of the erubáz soils. For the classification of the soil profiles, a hierarchic cluster-analysis was done with simple chain method. Euclidian square distance and Z score standardizing were applied for the measurements. Non-hierarchic K-mean cluster-analysis was performed with Z score standardizing by 2 cluster setting. The PEARSON relationship was applied during the correlation-analysis. ESRI ArcView 3.3 was used for map composition, graphic presentation and area measurements. The digital elevation model was prepared by the ArcView 3.3 and Surfer 8 softwares. Figures were created by CorelDraw 11.

Results and Conclusions

1. Applying the above described methodology (humus-content, UNGER -test, mineralogy and clay-mineralogy, cluster-analysis etc.) I concluded that based on the characteristics of their physical, chemical and mineralogical composition, two groups of the erubáz soil could be distinguished. The first group has developed on basaltic rocks, the second group has formed on andesitic lithology. These two groups can be regarded as the two sub-types of the *erubáz* soils. No mineralogical and clay-mineralogical examination was done about the soils developed on ignimbrite, however standard laboratory analysis suggests that they are in relationship with the andesitic group. Accordingly, the two sub-types were named as erubáz soils developed on BASIC and on NEUTRAL-ACIDIC lithology.

2. On areas of neutral-acidic lithology (andesite, ignimbrite) two varieties could be distinguished by colour and humus-content: the BLACK and BROWN *erubáz*. As a consequence of the differences of water-supply, temperature, and pH of the soils, the way of decomposition of the organic material is markedly different in the two varieties. The brown erubáz may be regarded as a transitional soil towards the brown forest soils, however still without stratification. While the black erubáz soils are easy to recognize on the field by their colour, distinction of the brown erubáz from brown forest soils in the surrounding areas is difficult.

3. On basic rocks (basalt) varieties could not be distinguished.

4. According to the mineralogical and clay-mineralogical analyses of the profiles, composition of the parent material is still well reflected by the mineral assemblages of the soils, which is the main reason for the distinction of the sub-types (basic, neutral-acidic). Presence of the instable mafic silicates indicates that composition of the parent material is still well reflected in the examined soil profiles. These minerals are absent, or present only in very small quantity in other soil types. Amphiboles and pyroxenes are the most important of this group, which are characteristic of the volcanic parent materials in the study areas. The amphibol is typical only in andesitic areas, while pyroxene is common in both lithologies. Among the examined soil profiles, pyroxene was characteristic primarily on soils of basaltic rocks.

5. A common characteristic of all samples is that they possess less quartz and significantly more feldspar than it is usual in other Hungarian soil types. The amount of quartz is usually higher in the upper soil, which indicates the presence of aeolian dust in the soil material.

6. Typically poor crystallisation of the secondary minerals demonstrates that they are in the early stage of their pedogenic evolution.

7. According to my investigations, the illite is the most frequent clay-mineral, which is followed by the kaolinite and the smectite. Further characteristic of the illite and of the kaolinite – besides the poor crystallization and disordering – is the common presence of smectite interlayering. As a maximum of 15-20% smectite interlayering may be present in the kaolinite, while in the smectite/illite group contains only cca. 10% interstatified smectite.

8.a) For the analysis of the mechanical composition of the soils with high organic material content, a methodological experiment was performed. This experiment verified that the Na-pyrophosphate sample preparation method is not suitable for these soil types. The international "A" preparation method (using H_2O_2) with at least 6 hours shaking proved to be the best way to smash the humic materials, because the measured clay-content increased significantly as a consequence of the improved disintegration of the micro-aggregates. Joint application of the two methods makes possible to determine the size of the (micro-)aggregates bound by the humic material. In some profiles the cementation by sesquioxides may also be considerable, which may require further sample preparation steps.

8.b) Based on results of the examinations using the Na-pyrophosphate sample preparation method, – contradicting to the expectations – all the profiles belong to the loamy texture class. Objective of the methodological experiment was the maximal possible disintegration of the aggregates, which could allow the classification of the profiles on basis of their real mechanical composition. With the method using H_2O_2 (with 6 hours shaking of the sample) the relative amount of the clay increased significantly, however the mechanical class of the profiles did not change considerably.

9. Mapping in the High-Börzsöny study area focussed on a better understanding of the morphological setting, areal extension and appearance of the andesitic erubáz soils. On the basis of the 1:25 000 scale soil map and 1:10 000 scale geomorphologic sketch, the followings can be stated:

a) The black erubáz soils developed on andesite are found on hilltop levels and narrow ridges, as it was mentioned by the classical definition of STEFANOVITS. Presence of the black erubáz is typical only in a few meters wide zone on the ridges, further on the slopes they are replaced by brown erubáz. With the exception of a small patch, the black erubáz soils occur above 700 m asl, which is an interesting feature of the Börzsöny area, as on the other study sites this soil was described from considerably lower altitudes.

b) The presence of brown erubáz soils cannot be connected to certain geomorphic elements or to a certain exposure direction, they occur everywhere on lower ridges and slopes. Its occurrence is determined by soil-climatic conditions. Mainly it develops on locations where moisture and temperature conditions permit the decomposition of organic material, but the geomorphologic position and/or the temperature- and moisture conditions are not adequate for the formation of the typical layered structure of the forest soils.

According to my study, general properties of the erubáz soils are as follows:

10. *Sub-type of erubáz soil developed on basic lithology.* Formation of this sub-type takes place on regolith of basic rocks. Their best known occurrence in Hungary is found on the basaltic mesas of the Tapolca basin. Well developed profiles are located on the hilltops, on the hillsides erubáz soils may occur only in small patches, mingled with thin stony soils. Depth of the profiles may be as small as 20 cm, but not even the thickness of profiles developed on flat, undisturbed surfaces exceeds 50 cm. The average thickness is 36 cm.

High humus content (Ah_1: 11%; Ah_2: 8%, shortened in the following as 11/8), slightly acidic pH value (pH_{H2O} 6.1/6.2; pH_{KCl} 5.6/5.7) and favourable N supply (13.5:1/12:1) are typical of the erubáz soils. Their colour is very dark brown or black both in wet (10YR 2/2, 10YR 2/1) and dry (10YR 2/2, 10YR3/2) state. Their structure is crumb, granular in dry state sometimes dusty. Their texture is mostly loam, rarely sandy loam (clay content 25/28, loam content 24/23). The humic layer consists of strongly bonded organic material and clay minerals. Dominant clay mineral of the sub-type is the illite, I/S (54/54), while the caolinite is present in 10%/14%. Proportion of the quartz (12/7) and feldspar (11/13) is similar to that of the caolinite, while proportion of the smectite – formerly supposed to be the dominant – usually remains below 10%. Calcium prevails among the exchangeable cations, their base saturation is high. Carbonated calcium is present only in the profiles of Tihany developed on basalt pyroclastites, which increases their pH to neutrality. Vegetation on top of the basalt volcanoes, sample sites of the basic subtype of the erubáz soils, is closed siliceous cliffs grassland, while on the hillsides oak-hornbeam forests, white oak low woods are be found.

11. *Sub-type of erubáz soil developed on neutral-acidic lithology.* Two varieties were distinguished: the *black erubáz* is present in a mosaic-like pattern on the higher ridges and hilltops of volcanic hills, while the *brown erubáz* developed on a considerably larger area on lower ridges and slopes, alternately with brown forest soils. Brown erubáz soil covers the ignimbrite slopes of the Bükkalja, too. These soils are thicker then the basic sub-type with an average of 43 cm, but profiles deeper than 60 cm are unusual. As a consequence of the significant microbiological activity, humus content of the brown variety remains around 4% (5/2). On the other hand, humus content of the black erubáz, characterized by extreme microclimatic conditions is around 10% (11/8). MUNSELL colour of the latter is similar to that

of the erubáz soils developed on basalt, while the brown erubáz is dark grayish-brown–brown (10 YR 4/2, 4/3, 5/3) in dry and very dark grayish-brown–dark brown (10 YR 3/2, 3/3) in wet state. Similarly to the basic erubáz, this sub-type is also slightly acidic, with favourable N-supply, but characterized by somewhat lower values. Their structure is crumb, in dry state dusty. Their texture is loam, rarely clayey-loam. The humic layer consists of strongly bonded organic material and clay minerals, like in the basic sub-type. Most frequent clay minerals in both varieties are the caolinite (15-30%) and the illite (13-20%, in some cases up to 90%, e.g. Tokaj Hill). The smectite is present in smaller quantities (5-8%). As a consequence of the presence of the smectite, in case of tough drying, which is infrequent in forest environment, fissures 1-2 cm wide may form. The opal-crystoballite and the crystoballite occur only in andesitic samples, where these are typical. The goethite is characteristic mineral of samples from the Börzsöny. The calcium is predominant among the exchangeable cations of the neutral-acidic erubáz soils, their base saturation is high. No carbonated calcium is present. According to their classical description, their flora consists of scattered degenerated individuals, which statement is not fully supported by my field observations. At a few exposed localities with thin soil cover some areas suit the above description, but on the majority of the areas covered by erubáz soils – depending on the altitude – well developed oak and beech forests are found. Nevertheless, vegetation is usually determined by the anthropogenic activities and their intensity (deforestation, viticulture etc.).

12. It may seem to be obvious to insert the Hungarian erubáz soils in the Andolol group of the international WRB system. In this system soils are classified on the basis of strict and quantified diagnostic properties, which allow an objective classification. Surprisingly the erubáz soils did not fulfil the criteria of the Andosols. Most of them fell into the group of Phaeozems and some proved to be more similar to the Leptosols, Luvisols and Cambisols. Originally, Phaeozems are mineral soils of steppe areas and their formation is controlled by climatic conditions and by the vegetation. In other words, the WRB-system emphasizes “steppe-like” features of the erubáz soils, while the effect of the volcanic parent material remains in the background. Andosols are usually developed on fresh volcanic material however, they were described from several million year-old volcanites of Central Europe, too. Consequently, as appropriate lithology is present in Hungary, formation of the Andosols is hindered by climatic conditions, mainly the absence of large amount of precipitation and of intensive weathering.

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