Volcanic soils of the High Börzsöny and their relationship with geomorphological conditions

Madarász, Balázs[1]–Jakab, Gergely[1]

Abstract

Heretofore very little research has been done on a specific soil type in Hungary called „erubáz", which develops on volcanic rocks. Its largest uniform and unbroken spot is located in the central part of Börzsöny Mountains (High Börzsöny). It is assumed that in reality this spot extends beyond its contours indicated in the soil map of the area. The main objective of the research project was to carry out a detailed analysis of this soil type and to identify its subtypes and varieties. A large scale soil mapping (1:25 000) and geomorphological mapping (1:10 000) was performed in order to determine the spatial distribution of the subtypes and varieties and to investigate the relationship between the territorial extension and geomorphological position. The sampling network was set after a thorough study of environmental conditions (e.g. relief, botanical conditions etc.). 38 soil profiles and 115 boring samples were taken by Pürckhauer auger because of the significant inhomogeneity of the studied area. Our former studies (Madarász, B. 2009) revealed that two varieties of the s-called '*erubáz*' soil, i.e. the brown and the black erubáz can be distinguished in the study area. Black erubáz soils occur on narrow ridges with high elevations as described in the classical definition by P. Stefanovits. After a few 10 meters from the crest of the ridges downslope they will be replaced by the brown erubáz. The latter can be found on the top of the ridges and on their slopes as well whilst the black erubáz appears only above 700 m a.s.l. except one smaller spot. The occurrence of the brown erubáz is controlled by soil climatic conditions. It develops mainly where enough moisture and heat are available for the decomposition of organic material but they are not sufficient and the geomorphic position is not suitable for the development of forest soils.

Keywords: erubáz soil, High Börzsöny study area, DEM, sampling, laboratory analyses

Introduction

One of the most ignored and less studied soil types in Hungary is the so called erubáz or *fekete nyirok* (black, wet soil), a special soil type developed on volcanic rocks. The main reason for this negligence is the fact that this soil occurs in small patches dispersed in the hilly regions of the country, which

[1] Geographical Research Institute, Hungarian Academy of Sciences. H-1112 Budapest, Budaörsi út 45. E-mail: madaraszb@mtafki.hu, jakabg@mtafki.hu

are outside the scope of agriculture. Because of its inferior role in agricultural mass-production and small areal extent, only the forestries and some vineyards are interested in studying these soils.

In the 1950's Stefanovits, P. dealt also with soil types of no major agricultural importance so that his investigations included the forest soils, too. Consequently, the erubáz soil was also included in his genetic soil classification system as an independent soil type (Stefanovits, P. 1951, 1956, 1959; Stefanovits, P.–Szűcs, L. 1961). Since then very little has been done and very few data were assembled on this soil type (Góczán, L. 1968, 1970; Néráth, M. 1997; Szendrei, G. 1998; Barczi, A. 2000; Fehér, O. *et al*. 2006; Fehér, O. 2007). Recently a detailed characterisation of the erubáz soils was provided by Madarász, B. (2009).

The surface occurrence of the erubáz soil can be estimated on the basis of the 1:100,000 scale agrotopographic map of Hungary. According to this map most of the volcanic landscapes are covered by 'brown forest soils with clay illuviation' (luvisols) and 'brown earth' (cambisols), since these soil types are typical under the climatic conditions of Hungary. The areal extension of the erubáz soil is limited to the Börzsöny–Visegrád Mountains and to the basaltic mesas of the Tapolca Basin, covering an area of 44 km^2 altogether, with the largest spot in the High Börzsöny. However, erubáz soils may occur on considerably larger areas than suggested by the agrotopographic map, only their tiny spots dispersed in a mosaic-like pattern are impossible to visualize at this scale.

During the last half-century several soil maps were prepared on the High Börzsöny area. First of these was the 1:200,000 scale genetic soil map prepared by Stefanovits, P. and Szűcs, L. (1961). The above mentioned agrotopographic map was published in 1982. In this map two soil types are shown within the study area, i.e. the 'brown forest soils with clay illuviation' (luvisol) and the erubáz, the latter with the largest areal extension in the country. Láng, S. (1955) in his book entitled "Physical geography of the Mátra and the Börzsöny" modified the version of the Stefanovits–Szűcs map already available in 1954. Járó, Z. (1978) published in his study a special soil map (1:200,000), where ranker soil covers almost 95% of the area. This must be treated with reservations as rankers are 'shallow soils affected by the parent material' developed on massive silicate rocks, but not on volcanic rocks, provided that the soil type developed on volcanites is the erubáz itself. The above mentioned maps are small-scale ones as no large-scale soil mapping was conducted in the Börzsöny Mountain so far which could provide detailed information of the areal extension and properties of the erubáz soil.

The present paper is aimed to report about a detailed field and laboratory analysis of this scarcely known soil type. In the Hungarian genetic soil classification system only the erubáz soil type exists, no sub-types and varieties have been specified. However, it became obvious at the beginning of the study that this soil type is far from being uniform as it is suggested by its classical definition. The large scale geomorphic mapping (1:10,000) and soil mapping (1:25,000) carried out by the authors in the High Börzsöny study area were aimed to understand the soil types of this area better, to describe the erubáz soil, to identify its sub-types, to learn more about the geomorphological position and to reveal the areal extension and appearance.

The study area

Topography and landscape evolution

The Börzsöny Mountains belong to the inner-Carpathian volcanic chain having mid-Miocene origin. It is the third largest volcanic region of Hungary, containing three topographic micro-regions. The major part of the study area is located in the Central (High) Börzsöny micro-region and some areas close to its boundary belong to the foothills of the Börzsöny (Marosi, S.–Somogyi, S. (eds.) 1990). The calc-alcaline intermediary volcanism in the High Börzsöny (16.5–13.5 Ma) produced block-and-ash-flows and lava flows mostly of pyroxene andesite (Pantó Gy. 1970; Balla Z. 1978; Karátson D. 1997, 2007). The study area (45.9 km^2) includes the highest part of the central caldera rim (Karátson, D. 2007) together with its inner slopes of easterly aspect and with the outer slopes of westerly aspect. The study area has a radial valley network.

As a result of the Pleistocene periglacial landscape evolution the slopes above 500 m asl. are mainly covered by rock debris, stones and are disrupted by cryoplanation steps (Szabó J. 1996). Physical weathering by frost destroyed more the lava strata of bedded lava rocks, while erosion carved tower-like rock formations of the more resistant block-and-ash-flow deposits (e.g. Katalin-szikla, Szabó-kövek).

The caldera rim, i.e. the Nagy-Hideg-hegy–Csóványos–Magosfa range of 800–900 m altitude forms the central part of the study area. The altitude of the study area ranges between 275 and 939 m *(Fig. 1).* It is poorly dissected, with a frequent occurrence of steep slopes and rock debris fields. Slopes are steeper than 25% on ca. 80% of the area and 35% on its 54%, *(Figs 2* and *3).* The relative relief decreases towards the boundaries of the study area from 350–370 m/km^2 to 100–150 m/km^2 (Kertész Á. 1976, 1978). Most of the slopes are exposed to west – north-west and to east–south-east *(Fig. 3).*

Climate

Climate is of primary importance in determining the conditions of soil formation. The study area belongs to the cool-wet climate type, where the annual

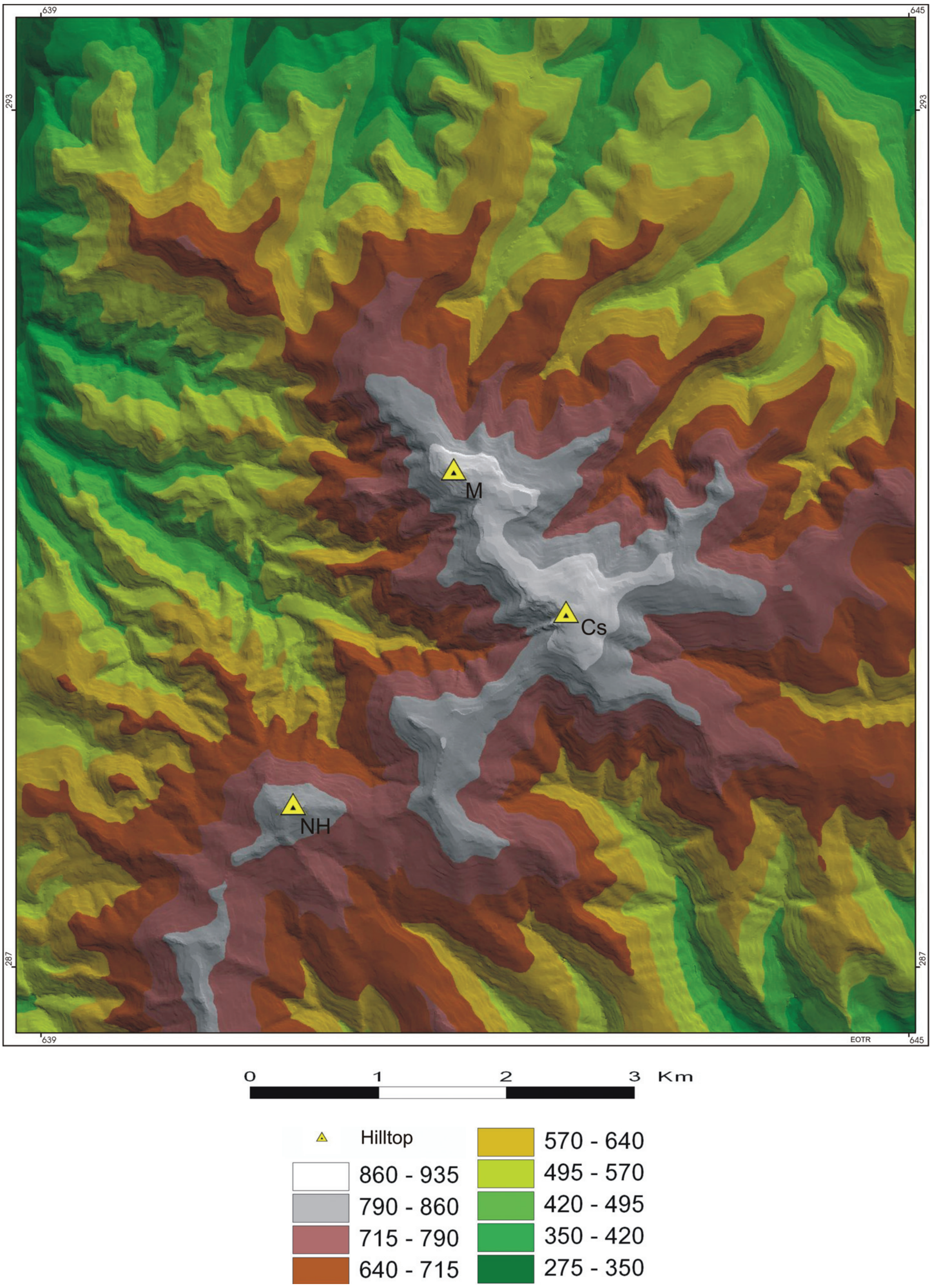

Figure 1. TIN digital elevation model of the High Börzsöny study area, (m). Abbreviations: NH = Nagy-Hideg-hegy, Cs = Csóványos; M = Magosfa

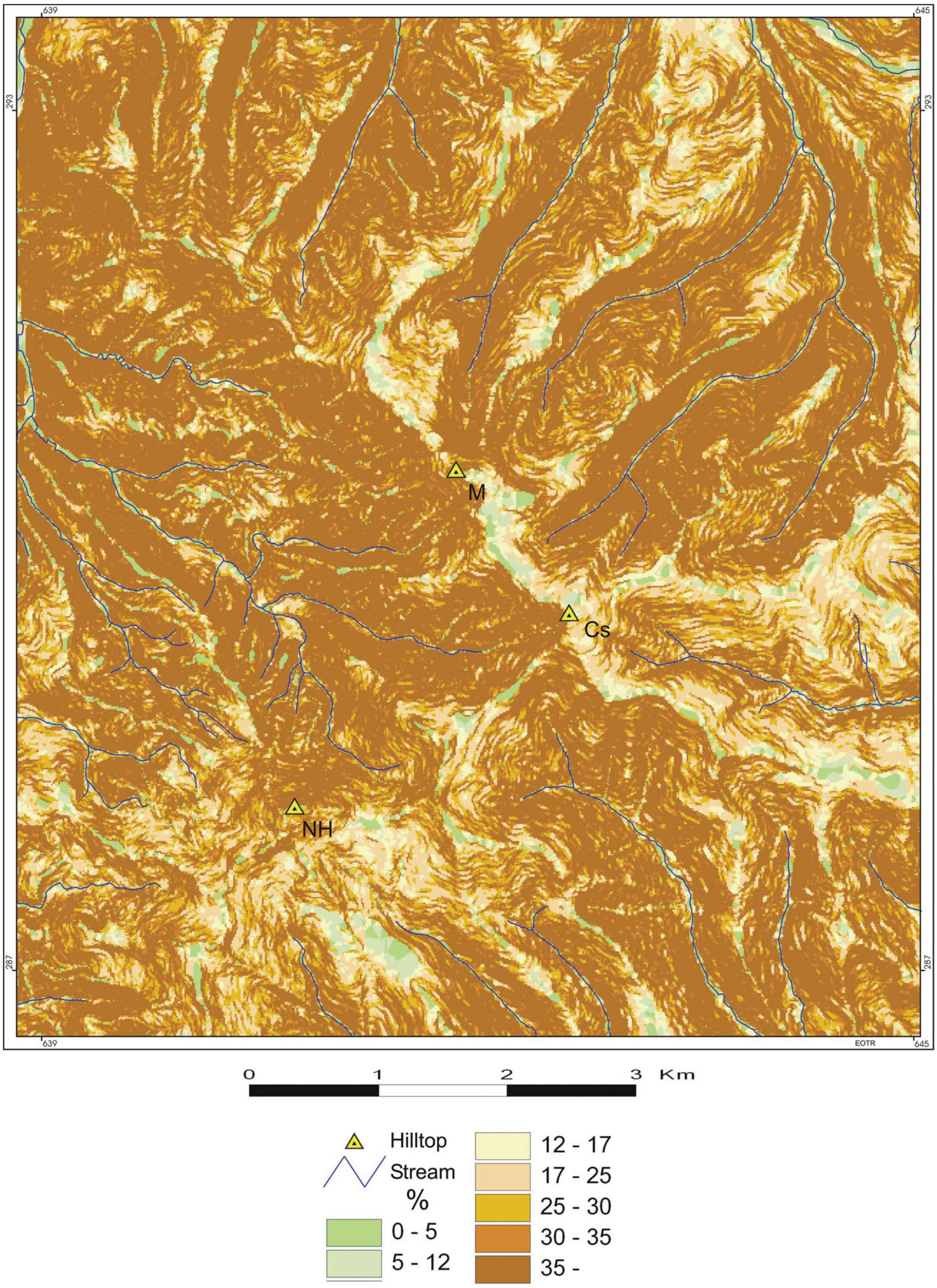

Figure 2. Slope gradient map of the High Börzsöny study area, (%). Abbreviations see in *Figure 1.*

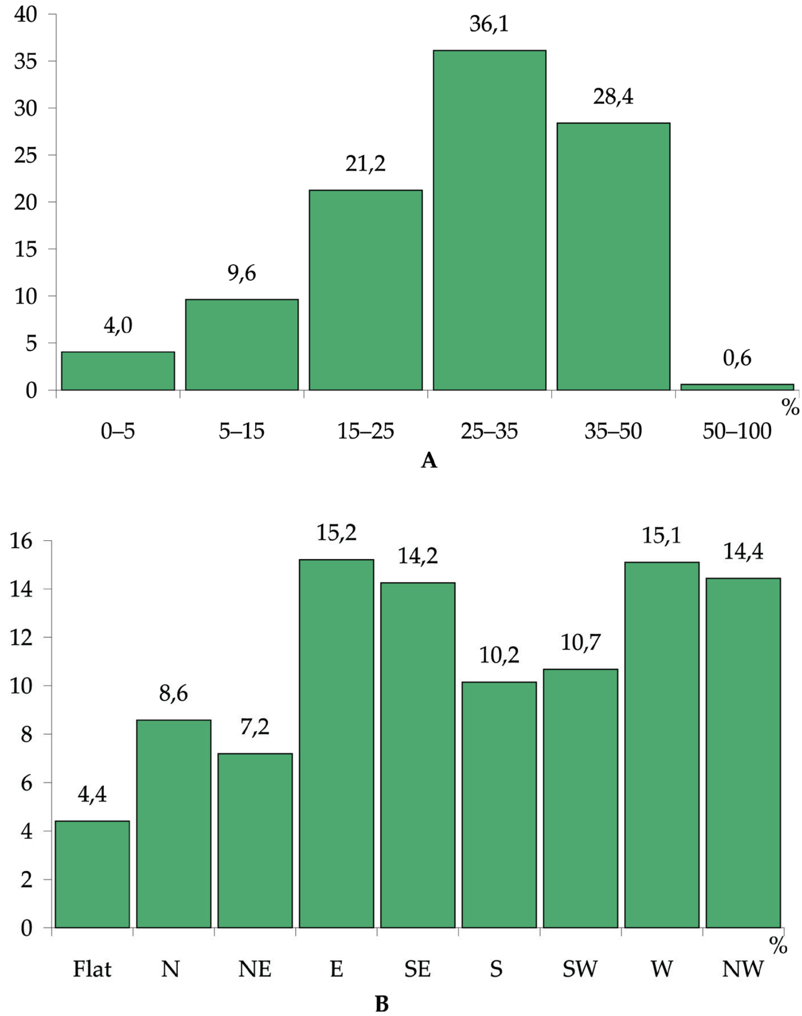

Figure 3. Slope gradient (A) and slope aspect (B) frequency histograms of the High Börzsöny study area

mean temperature remains below 8–8.5 °C. The winter is long and cold and frost is always possible except in summer. The annual mean precipitation is 800 mm, which can be even more in the peak areas. Most of the precipitation arrives at the beginning of summer (May–June), while the second part of the summer is drier and more sunny (Péczely, Gy., 1978; Láng, S., 1955). The number of days with snow cover varies between 60–80 and 100–120 days in the lower and higher regions, respectively. Average thickness of the snow cover is 30–50 cm. The aridity index is 0.82–0.90 (Marosi, S.–Somogyi, S. (eds.) 1990)

The High Börzsöny is almost uninhabited; therefore the vegetation is still almost in a natural state in most of the area. 97% of the study area is forested. The vegetation is montane and submontane beech, forests developed on slope-debris and on rock surfaces, whereas clearings are covered by meadows and rock shrubs (Fekete, G.–Varga, Z., 2006). Part of the andesite rock-fields still is not forested; the growth of the trees is hindered by debris thickness and by the lack of moisture. On the thinner rock-debris, slope-debris forests and acidophilous forests have developed, the former mainly mixed with lime, ash and maple species, the latter mostly with beech, oak (*Quercus petraea)*, some sorb and birch (Kárpáti Z. 1952).

The most important locations of erubáz soils, like e.g. at the top levels on the caldera rim, are covered by ash (*Fraxinus excelsior*) *(Photo 1).* In the opinion of some experts this is of anthropogenic origin, in other words, the consequence of improper forestry policy of the distant past. The beech has considerable bearing only every 7–10 years, while the ash has seeds more frequently. The young ash tree requires light and presumably sunny habi-

Photo 1. Ash (*Fraxinus excelsior*) trees before sprouting on the caldera rim between Csóványos and Nagy-Hideg-hegy

tat, while the young beech grows well in the shadow. Herbivore big game likes young ash, but it consumes the beech only if nothing better is available. Accordingly, if a beech forest was cut in a period when the number of wild-game was low, the forest of saplings in this area was ash instead of beech. In other opinions the stretch of ash in beech forests is a natural process on drier areas with a shallow soil (Király, G. *et al.* 2008).

Methods

As a first step of the soil mapping 1:10,000 topographic maps and the 1:50,000 geological map (Korpás L.–Csillagné Teplánszky E. 1999) were used to establish the network of sampling sites. The main objective of the mapping was the identification of the extension and geomorphic position of the areas covered by erubáz soils. Altogether 38 soil profiles were excavated and 115 Pürckhauer-type auger samplings were performed. For sampling the principles of soil mapping were applied (Szabolcs, I. 1966; Buzás, I. 1988, 1993). The FAO (1990) standard was used for the description of soil profiles. The genetic soil horizons were named and characterized on the basis of Szodfridt, I. (1993) and Stefanovits, P. *et al*. (1999).

1:10,000 topographic maps were used as a basis of geomorpological mapping. The methodology and the legend of Pécsi, M. (1963, 1991) were applied for the mapping procedure.

Analysis of the soil samples was carried out in the laboratory of the Geographical Research Institute, in accordance with the certified standards. $CaCO_3$ content of the soil was measured using Scheibler's gas-volumetric method (Buzás, I. 1988). Inorganic carbon content was leached by the decalcification method developed in the Institute. Organic carbon content was measured using Tekmar Dohrmann Apollo 9000 NDIR spectrometer. Humus content of the soils was determined by the equation of Stefanovits, P. *et al*. (1999): Humus% = TOC% × 1,72. The determination of the pH value ($pH_{(H2O)}$; $pH_{(KCl)}$) was performed with the potentiometric method (Buzás, I. 1993; MSZ-08-0206/2-1978). The colour of the samples was identified by the Munsell colour scale under dry and wet soil conditions. Bulk density was measured on undisturbed samples of known volume, by drying in oven (Buzás, I. 1988, 1993).

After the disintegration of the aggregates the mechanical composition of the samples was determined using Fritsch Analysette Microtech 22 laser diffraction particle size analyzer. Mineralogical and clay-mineralogical analyses of the soils were performed applying X-ray diffraction method in the Geochemical Research Institute of the Hungarian Academy of Sciences by means of a PHILIPS PW 1710 equipment.

For map compilation and graphics as well as for area measurements the ESRI Arc View 3.3 was applied. ESRI Arc View 3.3 and Surfer 8 softwares were used for Digital Elevation Model construction.

Results

Evaluation of the soil map

Soil mapping is a difficult task in landscapes with dissected topography. However, based on field observation and laboratory analyses the relationship between topography and soil types can be identified thus facilitating the mapping procedure. The 1:10,000 scale geomorphological map provided a good and essential basis for the mapping, i.e. some soil types, like the erubáz soil occur mostly in typical geomorphic positions, on top levels, ridges and on steep slopes of southerly exposure *(Fig. 4).* In addition to this land mosaics can affect soil evolution processes (Szalai, Z. 2008; Szalai, Z.–Németh, T. 2008).

Parent materials are usually andesite lava and andesite block-and-ash-flow deposits. Their mineralogical, physical and chemical compositions are widely varied. Where the climate is moderately wet different associations of deciduous forests have developed and soil climate can be described as udic or mesic (Wernstedt, F.L. 1983).

Genetic soil types of the High Börzsöny study area

Below a short description is given about all soil types occurring in the High Börzsöny area. Their detailed description except for the erubáz soils is not provided here.

Skeletal soils (Lithosols)

A considerable area is occupied by stony skeletal soils *(Fig. 5),* especially where soil erosion is an important factor, so that products of weathering are removed from the slope immediately after their formation. They can be found on narrow ridges, small hilltops and on steep slopes. On the inner slopes of the caldera rim rock-debris slopes are encountered frequently as a consequence of Pleistocene periglacial frost riving. Soil formation in these areas is in its incipient phase.

The thickness of the soil cover is less than 10 cm. Soil patches alternate with rocky spots. Rock fragment proportion may reach 70–90%. These soils can

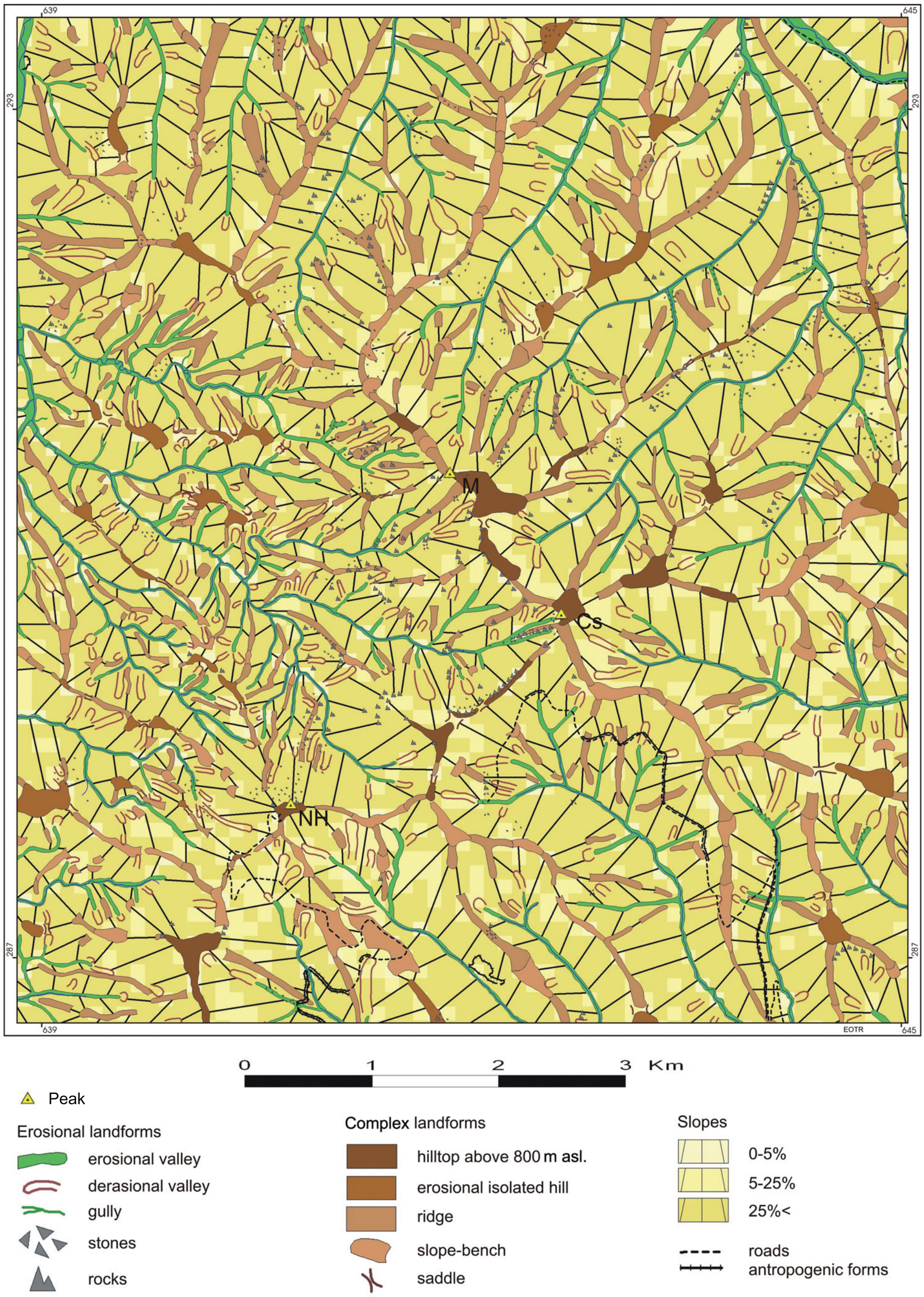

Figure 4. Geomorphological map of the High Börzsöny study area (1:10,000). Abbreviations see in *Figure 1*

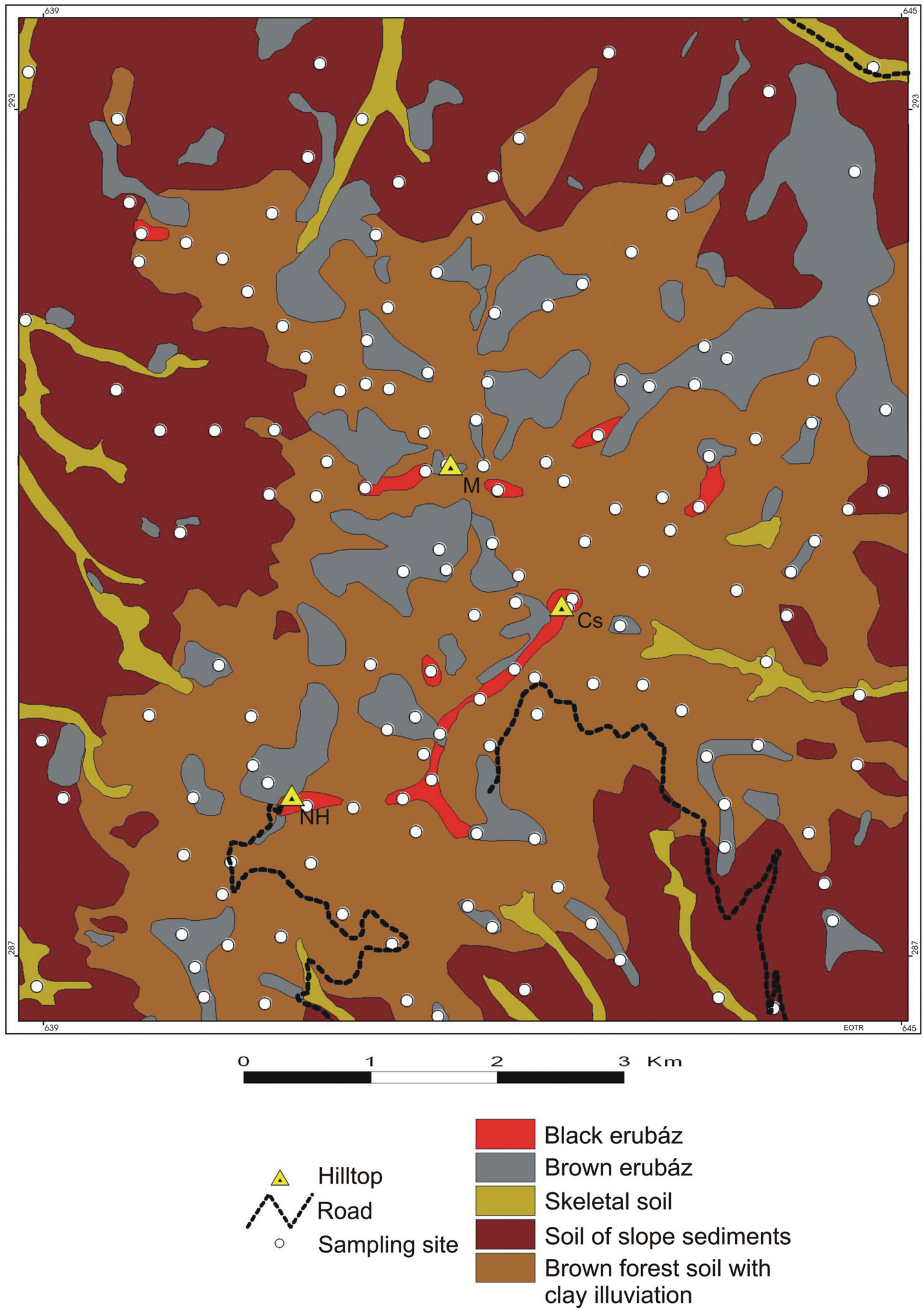

Figure 5. Soil map of the High Börzsöny study area (1:25,000). Abbreviations see in *Figure 1.*

be considered as thin erubáz-like soils, where the soil thickness could not reach the adequate depth. Spots of skeletal and erubáz soils occur in a mosaic-like pattern. Skeletal soils occur in areas with similar geomorphological position.

Shallow soils influenced by the parent material

Erubáz is the most widespread soil type of the study area *(Fig. 5).* Its humus content is very varied as a consequence of differing conditions of organic material decomposition. This diversity is the result of humidity, temperature and pH differences. According to the detailed studies of Madarász, B. (2009) the distinction of two sub-types, i.e. brown and black erubáz is necessary. The humus content of brown erubáz rarely exceeds 4% while that of black erubáz, exposed to extreme soil climatic conditions may reach 10%. The wet colour of the latter (10YR 2/2, 10YR 2/1) and the dry colour (10YR 2/2, 10YR 3/2) refer to dark brown or black colours. The brown sub-type is dark greyish-brown when dry (10 YR 4/2, 4/3, 5/3) and very dark greyish-brown or dark brown in wet state (10 YR 3/2, 3/3).

Scattered spots of black erubáz can be found on the highest levels of the study area, on the hilltops and ridges reaching the altitude of 750–915 m asl. The size of their area rarely exceeds 100 m^2. They vary with spots of stony skeletal soils *(Figs 4* and *5).*

The geomorphological survey revealed that potential areas of the occurrence of erubáz soils are very restricted in the study area. The fairly narrow ridges are only rarely interrupted by slope terraces. Hilltop areas and erosional inselbergs are not predominant, steep slopes dissected by rock fields prevail. According to the geomorphological sketch of the area the percentage suitability of the landforms for the development of erubáz soils is as follows: 1% hilltop areas, 1.5% erosional inselbergs, 8.3% intervalley ridges and 2.9% slope terraces. In spite of this percentage values erubáz soils can be found only on 1.1% of the study area. Brown erubáz soil shows a significantly larger territorial extension. It may develop practically everywhere from the hilltops to the valley sides as its occurrence is not associated with special landforms or slope exposures. In locations where the specific conditions of the formation of black erubáz are not fulfilled, i.e. biological decomposition hindered by winter freezing and summer drought (Madarász, B. 2009), brown erubáz soils have developed.

Their spatial appearance is less mosaic-like than that of the black erubáz forming large continuous soil patches. Brown erubáz soils can be regarded as a transition from black erubáz towards the ‘brown forest soils with clay illuviation’, the differentiation of soil horizons however cannot be observed yet.

The erubáz soils of the Börzsöny Hills have a slightly acidic pH and their N supply is favourable. Their structure has a granular character and in dry state it is dusty frequently. The average depth of the profiles is 43 cm. They have usually a loamy or sometimes a clayey-loamy texture. The organic material and the clay minerals form a strongly bonded humic horizon. Characteristic clay minerals are caolinite (15–30%), illite (10–20%) and smectite (5–10%). Although severe desiccation of the soil under a forest occur only rarely in the presence of a considerable amount of smectite 1–2 cm wide fissures may develop. There is an abundance in opal and christobalit and goethit is also a major component. Calcium is the most important exchangeable cation. Their saturation is low and no $CaCO_3$ is present in the soil of the study area (Madarász, B. 2009).

According to the classical description the vegetation cover developed on erubáz soils consists of scarce and degenerated specimens. Our field studies do not support this statement. At some locations on shallow soils with transitional character towards skeletal soils the forest was degenerated while in most areas covered by erubáz soils well developed oak and beech forests were found. Nevertheless, vegetation is usually determined by the anthropogenic activities and their intensity.

'Brown forest soils with clay illuviation' (Luvisols)

As a consequence of topographic and climate conditions subtypes of the 'brown forest soils with clay illuviation' are the most widespread soil types of the study area. Their profiles are best developed on gentle slopes and slope terraces. On steeper slopes their profile as a rule is truncated. They occur mostly at altitudes under 600 m asl. as a consequence of slope steepness and dissected topography. *(Figs 4* and *5).*

Slope debris soils

The eroded material is accumulated mainly in the valleys. Its thickness may reach several meters. Accordingly, slope debris soils can be found at lower elevations on the valley floors. Their presence is considerable only in the widened valley floors at the border of the study area (*Figs 4* and *5).*

Conclusions

In the course of the large-scale soil mapping in the High Börzsöny study area the following soil types were identified: skeletal soils, brown forest soils with clay illuviation, slope-debris soils and erubáz soils (affected by parent material). Two subtypes of the erubáz soil are described as the black and the brown erubáz.

Black erubáz soils occur on high and narrow ridges, in accordance with the classical definition of Stefanovits. Their development is associated with specific soil-climatic and topographic conditions, namely to the zone of biological decomposition hindered by severe winter freezing and summer drying. They are present only in a few 10 meters width on the ridges, along the slopes they are replaced by brown erubáz soils. Except for one small patch the black erubáz soil appears above 700 m asl. At the same time the brown erubáz soil may occur everywhere on lower ridges and slopes. Its development is also controlled by soil climate i.e. it develops at locations where the moisture and heat are high enough for the decomposition of organic material but the conditions are not sufficient for the development of characteristic horizons of the 'brown forest soils with clay illuviation'. Besides their Munsell-colour the threshold value of 6% humus content was used for the differentiation of the two sub-types. Mineralogical and clay-mineralogical analysis of the erubáz soils did not show significant difference between the brown and black erubáz soils.

Acknowledgements: Thanks are due to the HAS Geochemical Research Institute and personally to dr. Tibor Németh who performed the X-ray diffraction analysis and for the students in geography of the Eötvös Loránd University who participated in the 2007 summer field campaign in the High Börzsöny area.

REFERENCES

Balla Z. 1978. A börzsönyi paleovulkán rekonstrukciója. – Földtani Közlöny *108.* pp. 119–136.

Barczi A. 2000. A Tihanyi-félsziget talajai. – Bakonyi Természettudományi Múzeum, Zirc. 125 p.

Buzás I. (ed.) 1988. Talaj- és agrokémiai vizsgálati módszerkönyv 2. – Mezőgazdasági Kiadó Budapest, pp. 37–41.

Buzás I. (ed.) 1993. Talaj- és agrokémiai vizsgálati módszerkönyv 1. – INDA 4231 Kiadó. Budapest, pp. 37–41.

Fehér O.–Füleky Gy.–Madarász B.–Kertész Á. 2006. Hét vulkáni kőzeten kialakult talajszelvény morfológiai és diagnosztikai jellemzői a hazai genetikai talajosztályozás és a WRB (World Reference Base for Soil Resources, 1998) szerint. – Agrokémia és Talajtan *55.* 2. pp. 347–366.

Fehér O. 2007. A talajviszonyokra ható természeti és emberi tényezők vizsgálata a Kárpát-medence néhány jellegzetes táján. – Doktori értekezés, Szent István Egyetem, Gödöllő. 134 p.

Fekete G.–Varga Z. 2006. Magyarország tájainak növényzete és állatvilága. – MTA Társadalomkutató Központ, Budapest, 461 p.

Góczán L. 1968. „Erubáz" mészlepedékes csernozjom a Tihany-félszigeten – Földrajzi Értesítő *3.* pp. 375–378.

Góczán L. 1970. A Tihanyi-félsziget talajviszonyai. – In: Láng G. (szerk.) Magyarázó a Balaton környéke 1:10 000-es építésföldtani térképsorozatához, Tihany. Magyar Állami Földtani Intézet, Budapest, pp. 67–69.
Járó Z. 1978. A Börzsöny erdőfedte talajainak általános jellemzése és értékelése az erdőgazdálkodás szempontjából. – In: Somogyi S. (ed.) A Börzsöny hegységnek és környékének agrogeológiai vizsgálata. Agrogeológiai sorozat, Nagy és középtáj szintű agrogeológiai vizsgálatok, MTA FKI Budapest, 325 p.
Karátson D. 1997. A vulkáni működés és kalderakérdés a Börzsönyben. – Földrajzi Közlemények *121.* 3–4. pp. 151–172.
Karátson D. 2007. A Börzsönytől a Hargitáig, Typotex, Budapest. 463 p.
Kárpáti Z. 1952. Az északi hegyvidék nyugati részének növényföldrajzi áttekintése. – Földrajzi Értesítő *1.* pp. 289–315.
Kertész Á. 1976. A morfometrikus módszerek alkalmazása a geomorfológiai kutatásokban. – Földrajzi Értesítő *25.* 2–4. pp. 237–248.
Kertész Á. 1978. A Börzsöny-hegység relatív relief térképei. – In: Somogyi S. (szerk.): A Börzsöny hegységnek és környékének agrogeológiai vizsgálata. Agrogeológiai sorozat, Nagy és középtáj szintű agrogeológiai vizsgálatok, MTA FKI Budapest, 4 p. + 4 ábra.
Király G.–Molnár Zs.–Bölöni J.–Csiky J.–Vojtkó A. (szerk.) 2008. Magyarország földrajzi kistájainak növényzete. – MTA ÖBKI, Vácrátót. 248 p.
Korpás L.–Csillagné Teplánszky E. 1999. A Börzsöny–Visegrádi-hegység és környezetének fedetlen földtani térképe, M=1:50 000. – Magyar Állami Földtani Intézet.
Láng S. 1955. Mátra és a Börzsöny természeti földrajza. – Akadémiai Kiadó, Budapest. 512 p.
Madarász B. 2009. A magyarországi erubáz talajok komplex talajtani vizsgálata, különös tekintettel agyagásvány-összetételükre. – PhD thesis, Loránd Eötvös University.
Marosi S.–Somogyi S. (szerk.) 1990. Magyarország kistájainak katasztere. – MTA Földrajztudományi Kutatóintézet, Budapest. 1023 p.
Néráth M. 1997. Rendzina és nyirok talajok jellemzése és osztályozása a talajok tulajdonságai alapján. – GATE, Talajtani és Agrokémiai Tanszék, Gödöllő. Szakdolgozat. 90 p.
Pantó Gy. 1970. A Börzsöny hegység északi részének harmadidőszaki vulkanizmusa. – In: Kubovics I.–Pantó Gy. (szerk.): Vulkanológiai vizsgálatok a Mátrában és a Börzsönyben. Akadémiai Kiadó, Budapest. pp. 161–302.
Pécsi M. 1963. Magyarország részletes geomorfológiai térképeinek jelkulcsa. – Budapest. 24 p.
Pécsi M. 1991. Geomorfológia és Domborzatminősítés – MTA Földrajztudományi Kutatóintézet, Budapest, 296 p.
Péczely Gy. 1978. A Börzsöny hegység éghajlata. – In. Somogy S. (ed.) 1978. A Börzsöny hegység regionális agrogeológiája. MTA Földrajztudományi Kutatóintézet, Budapest.
Stefanovits P. 1951. Andezittufán kialakult talajok a Börzsöny hegységben. – Agrokémia és Talajtan Tom. *1.* No. *3.* pp. 309–317.
Stefanovits P. 1956. Magyarország talajai. – Akadémiai Kiadó, Budapest. 252 p.
Stefanovits P. 1959. A magyarországi erdőtalajok genetikus-talajföldrajzi osztályozása. – Agrokémia és Talajtan Tom. *8*. No. *2*. pp. 163–181.
Stefanovits P.–Szücs L. 1961. Magyarország genetikus talajtérképe és magyarázó. – OMMI pp. 34–35.
Stefanovits P.–Filep Gy.–Füleky Gy. 1999. Talajtan. – Mezőgazda Kiadó, Budapest. 470 p.
Szabó J. 1996. Csuszamlásos folyamatok szerepe a magyarországi tájak geomorfológiai fejlődésében. – Habilitációs értekezések, Kossuth Egyetemi Kiadó, Debrecen. 223 p.

Szabolcs I. (szerk.) 1966. A genetikus üzemi talajtérképezés módszerkönyve – Országos Mezőgazdasági Minősítő Intézet, Budapest. 428 p.
Szalai, Z. 2008. Spatial and temporal pattern of soil ph and eh and their impact on solute iron content in a wetland (transdanubia, Hungary). – AGD Landscape & Environment *2. 1.* pp. 34–45.
Szalai Z.–Németh T. 2008. Elemi táji mintázatok hatása talajkémiai paraméterekre. – Földrajzi Értesítő *57.* 1–2. pp. 135–146.
Szendrei G. 1998. Talajtan. – Eötvös kiadó, Budapest. 160 p.
Szodfridt I. 1993. Erdészeti termőhelyismerettan. – Mezőgazda Kiadó, Budapest. pp. 176–179.
Wernstedt, F.L. 1983. World climatic data. Hungary. – Dossier nr. 128. Gent University, Manuscript.