Do Andosols Occur in the Czech Republic?

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Abstract: The aim of this contribution was either to confirm or refuse the supposition that there are soils on the volcanic effusive rocks in the Bruntál district which can be assigned to the referential group of Andosols. The conditions for the genesis of Andosols are described and the diagnostic criteria of the andic process are defined both according to the principles of the WBR/FAO 2006 classification and according to the Slovak MKSPS 2000 classification system. In the Czech classification system, the diagnostics of Andosols has not yet been described or defined because their occurrence on the territory of the Czech Republic has not been confirmed till now. On the Velký Roudný volcanic dome (780 m), samples from two profiles were taken and described: one from below the summit as a sample of forest soil, and the other from the terraced, grass-covered foot of the hill, formerly used as a ploughed land. The samples from the two profiles were processed, and analyses were carried out according to both the classification systems mentioned above. The results of the analyses were subsequently evaluated. It was discovered that both evaluated profiles conformed to most of the diagnostic characteristics of andic development according to both WRB 2006 and the Slovak 2000 classification systems. Both evaluated profiles could be then classified – according to WRB 2006 – as Vitric Andosol (Dystric) and Vitric – Umbric Andosol (Dystric, Colluvic), respectivelly; according to Slovak Classification System as Andic Cambisols. The occurrence of soils with andic development in the Czech Republic was thus confirmed. The conclusion drawn by some authors (eg. in US Taxonomy) that a higher content of volcanic glass and a substrate of andesite type are not an indispensable condition for the creation of soils classified as Andosols was also confirmed. Likewise, according to the WRB criteria, a melanic humus horizon is not a necessary condition. Because of the difficulties in distinguishing the types, the Czech classification system recommends that a humic andic horizon should be evaluated as molic. We assume that in some cases it could be better classified as umbric. A preliminary proposal has been put forward to insert the Andozem soil types in Taxonomic Soil Classification System of the Czech Republic: Haplic Andosol, Vitric Andosol, Lithic Andosol, Umbric Andosol, but the properties and criteria of those soils will have to be defined precisely. One problem which will also have to be resolved is how to allocate the profiles displaying andic properties either to the proposed subtype of Cambic Andosol or to the subtype of Andic Cambisol (outside the referential class of Andsols). This issue is, indeed, not dealt with satisfactorily either by the Slovak system or the worldwide WRB 2006 classification, either.

Keywords: Andosols; diagnostic characteristics; genesis; occurrence in the Czech Republic; proposal for Czech classification

For some time now, discussions have been going on among Czech soil scientists about whether Andosols occur in the Czech Republic. NĚMEČEK *et al*. (2001) refer to the fact that their occurrence has never been confirmed. Nevertheless, there have, been some studies (HOLUŠA 2003) which point to their occurrence. The problem, it seems, lies in the occurrence and extent of the basic condition for their creation, ie. the parent material. Practically all studies dealing with the Andosol classes insist on their genesis from rocks of andesite type. Andesite and its varieties are, however, rare in the Czech Republic. All forms of andesite are classified as neutral to basic, younger (tertiary or qua-

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ternary) effusive rocks, of which there are many (phonolite, trachyte, and, among the basic rocks, especially basalt-type rocks and their tuffs), but soils similar in type to Andosols have never been discovered on them. With andesites, approximately half the mass of the rock must consist of moderately basic plagioclases with a large proportion of coloured components (black micas, amphiboles, pyroxenes) and, above all, these minerals should occur in the form of volcanic glass, that is, in an amorphous, uncrystallised or only partly crystalline form (hemicrystalline structure).

In the Czech Republic, rocks of the andesite group occur in veins of trachyandesites in the Tepelská Highland, in the southern part of the Doupov Hills, and, locally, in the Bohemian Central Mountains (České středohoří). In Moravia, intrusive and effusive veins occur of both amphibolic trachyandesites and basalt andesites beneath the surface in the flysch layers of the White Carpathians (Bílé Karpaty) near Uherský Brod, all of them in forested areas (Stejskal 1958). In Slovakia the occurrence of rocks of the andesite type is more frequent in areas with tertiary volcanic hills, such as the Kremnické Hills, Slanské Mountains, Štiavnické Hills, Polana, Vihorlat or Inovec (Stejskal 1958; Šály 2000; Balkovič 2002; Juráni & Balkovič 2007).

Andosols, as typical soils of volcanic areas, have a specific morphology and specific physical and chemical properties. Their international and Czech name is, in fact, illogical, because in Japanese, the language from which the name has been derived, an-do means dark soil, so the suffix -sol is, therefore, tautological. Because of their characteristics, Andosols have become a separate group in all classification systems, whether they are considered to be an order, as in US Taxonomy, or class, as in the French classification system of 1995 or WRB-FAO (1998, 2006). In the Morphogenetical Soil Classification System (Hraško *et al.* 1991) as well as in the new Slovak classification (Sobocká *et al.* 2000) and in the new Czech classification (Němeček *et al.* 2001), Andosols are also listed as a referential group. One of the principal common characteristics of andic soils is their high content of humus (Amano 1988; Shoji & Otowa 1988 and others), which, in the humid and moderately humid conditions of the temperate zone, exceeds 8%, and sometimes even 20%. The humus in the thick surface horizons (often larger than 50 cm) is characterised by the predominance of fulvic acids over humic acids and a high C:N ratio (above 13). The nitrogen regime is characterised by retarded mineralisation and nitrification (Higashi 1983). The polymerisation of organic matter is not very high because the period in which the soil dries out is absent. The high humus content results from the creation of complexes of organic matter with the forms of active Fe or Al, or with minerals such as allophanes, imogolites or ferrihydrites released through the weathering of volcanic glass (Arnold 1988; Brady & Weil 2002; WRB 2006), and it determines the very dark colour (Munsell value and chroma below 3 when wet). These minerals are generally part of the weathering sequence of pyroclastic materials: tephric – vitric – andic properties are created. The weathering of minerals rich in silica in a humid or perhumid climate (corresponding to a ustic water regime according to US Taxonomy 1996) thus forms the conditions for a high level of stability of organic matter and its resistance to mineralisation. Despite their high humus content, these soils are generally acid, with a low content of basic cations (Tan 1984). As a rule, they are loamy or sandy-loamy. Their very distinctive characteristics are a low bulk density (below 0.9 g/cm^3), a high content of Fe and Al oxalates, and a high retention of phosphates. Generally, they have a wide range of potential fertility, ranging from poorly productive to highly fertile (Shoji *et al.* 1996; Brady & Weil 2002; Takahashi *et al.* 2004).

The milestone in the understanding of Andosols (the andic horizon) was their division into non-allophanic and allophanic. Shoji and Otowa (1988) define allophanic Andosols as those which originate from volcanic rocks rich in volcanic glass (basalts, basaltic andesites). A sufficient amount of basic cations saturates the sorption complex and prevents the extensive creation of organometallic complexes. Clay minerals such as allophane are thus created, which are remnants of tertiary weathering (Stejskal 1958). Non-allophanic Andosols originate from rocks such as andesite, rhyolite, and dacite. Their acidic character determines the creation of Al-Fe organometallic complexes and chloritised clay minerals. This division corresponds to the similar distinction in WRB (2006), in which the types of andic horizon are termed as the sil-andic type (allophane predominates) and alu-andic type (Al complexes with organic acids predominate). The sil-andic type is characterized by an acid to neutral reaction, while the reaction of the alu-andic type is extremely acid to acid (US Taxonomy). The degree of phosphorous (phosphate) retention is used as an indicator of andic properties, as a proof of its immobilisation (Soil Survey Staff 1999; WRB-FAO 1998, 2006; Sobocká 2000; FAO 2006).

The basic soil-forming process is the rapid weathering and transformation of the porous soil-forming substrate, the result of which is the creation of amorphous or very moderately crystalline silicate minerals (allophanes, imogolites, ferrihydrites). To a certain extent, this process constitutes a separate branch of the general process of weathering (Němeček *et al.* 1990).

Andosols are characterised by typical stratigraphy of their profiles, which is similar to that of Cambisols: O – Aa – Ba (Bva) – C (Němeček *et al.* 2001).

The basic diagnostic horizon of Andosols is the andic horizon Ba, which lies below the anhydromorphic humic andic horizon Aa, and is of melanic or molic type. The genesis of andic properties and characteristics is primarily determined by the usual soil-forming factors in the following order: rock – time – climate – relief – vegetation (Balkovič 2002). The substrate is volcanic rocks or their tuffs with a high content of volcanic glass: rhyolite, dacite, andesite, basaltic andesite, and basalt. Accessory minerals, including opal, cristobalite, halloysite, smectites, and other clay minerals significantly affect the soil formation. The content of volcanic glass in the rock, the degree of porosity, and its texture are important factors for weathering: more intensive weathering takes place in porous volcanic glass, and in glass with higher contents of Na, K, Ca, Fe or Al, whereas a high content of SiO_2 retards the weathering. Shoji and Otova (1988) and Arnold (1988) note, however, that although volcanic glass is a common component of most andesites and their tuffs, it is not an indispensable condition for the creation of soils assigned to the order of Andosols (Soil Survey Staff 1999). These are relatively young soils; Brady and Weil (2002) estimates their age at 5 to 10 thousand years. The genesis and transformation of Andosols with the emergence of developmental sequences depends, to a large extent, on climatic conditions (FAO 2006, WRB-FAO 2006). In our climatic conditions, a higher level of moisture, caused by the level of precipitation, is fundamental to their creation (Juráni & Balkovič 2007). In well drained soils in a moderately humid climate (a udic water regime), rapid leaching of silica acid is a typical phenomenon (Shoji *et al.* 1993). The washing-out of SiO_2 is supported by the movement of underground water determined by the relief of the terrain. The creation of allophanes is also supported by the washing-out of SiO_2. A high level of water binding and constantly high level of moisture also contribute to the build-up of humus during periodic anaerobiosis (Němeček *et al.* 1990). Vegetation, in turn, has a direct impact on the creation of the surface andic humic horizon.

According to WRB (2006), the andic horizon must have the following physical, chemical and, in some cases, mineralogical diagnostic properties:
– the content of volcanic glass in fine earth must be higher than 10%;
– the bulk density of the soil during momentary moisture must be 0.9 $g.cm^3$ or less;
– fine earth must contain at least 10% clay;
– the content of Al_{ox} + ½ Fe_{ox} in fine earth must be equal to or higher than 2%;
– the retention of phosphates in the anion capacity must be 85% or more; and
– the thickness of the andic layers must be at least 30 cm.

These basic characteristics may be supplemented with further possible characteristics of andic horizons:
– colour: the Munsell value and chroma must be < 3
– the humus content must be > 8%, normally > 20%, but < 25%
– in the ratio of fulvic acids to humic acids FA/HA, fulvic acids should predominate
– the ratio of carbon to nitrogen C:N must be high (> 13).

Vitric characteristics correspond to a lower level of weathering. According to WRB (2006), they are determined by the following characteristics:
– 10% or more volcanic glass in the fraction of fine earth, or:
– bulk density > 0.9 $g.cm^3$, or:
– less than 10% clay in fine earth, or:
– Al_{ox} + ½ Fe_{ox} > 0.4%, or:
– the retention of phosphates must be above 25%, and
– the thickness of the layer(s) with these characteristics must exceed 30 cm.

As with the andic properties, other characteristics may be added:
– colour: Munsell value and chroma below 3

– in the ratio of fulvic acids to humic acids, humic acids must significantly predominate over fulvic acids
– the ratio of C:N must be high.

WRB-FAO (2006), also describes the diagnostic criteria for the melanic and fulvic humus horizons.

The melanic horizon is defined as a thick, black horizon on or near the surface of the soil with a low bulk density and a high content of organic matter, which is the result of the decomposition of plant debris and rootage. According to WRB (2006), to be identified as melanic the horizon must display the basic characteristics of an andic horizon throughout its thickness.

According to WRB (2006), the fulvic horizon has similar criteria. The two horizons, melanic and fulvic, may be distinguished from each other only on the basis of the melanic index (Honna *et al.* 1988): a melanic horizon has an index < 1.7, while a fulvic horizon has an index > 1.7 throughout its thickness.

It should be emphasised that the concept of the melanic horizon in WRB-FAO (2006) is different from that found in the Czech TKSP classification (Němeček *et al.* 2001) or in the Slovak MKSPS classification (Sobocká *et al.* 2000). The Slovak classification system (Sobocká *et al.* 2000) presents somewhat simplified diagnostic characteristics. According to this system, Andic characteristics are:
– the content of Al_{ox} + ½ Fe_{ox} equal to or higher than 2%, or:
– the phosphate retention value > 85%
– bulk density equal to or lower than 0.9 g/cm^3
– exchangeable alkalinity pH equal to or higher than 9.4 in NaF,

with a further supporting characteristic – an increase in the allophane proportion with increasing depth.

The Slovak classification system also presents the characteristics of the melanic and metamorphic andosol horizons. The melanic horizon has:
– thickness > 10 cm
– more than 6% C_{ox} as a weighed average, and more than 4% C_{ox} in all layers
– some andic characteristics
– colour when moist: value equal to or lower than 2, chroma equal to or below than 3

The metamorphic andic subsurface horizon created by weathering should have the following characteristics:

(a) thickness > 15 cm
(b) alternative characteristics (only one of the following is necessary):
– chroma higher, or more reddish than in the C horizon
– the content of free Fe (coffin) is higher in the Bv horizon than in the C horizon
– a higher clay content in the B horizon than in the C horizon
– a more pronounced structure
(c) non-carbonate fine earth
(d) < 75% skeleton content
(e) it should not meet the criteria for the luvic, mottled, or spodic horizons.

In addition, it has bulk density below 0.9 $g.cm^3$ but does not meet the criteria for the andic horizon.

These characteristics formed the basis for evaluating the investigated profiles. No level of the volcanic glass content was set. This is not stated in the results.

MATERIAL AND METHODS

The impulse for this work was a brief report (Holuša 2003) stating that andosol had been found on the summit of Velký Roudný in the Bruntál district. This report met with no response from the soil science community. The possible occurrence of andosols in that and in others localities in the area with a similar geological origin (Venušina sopka, Slunečná, Uhlířský vrch, Malý Roudný etc.) had been presumed earlier, but had never been confirmed. This contribution deals therefore with a more detailed evaluation of the soils found in that locality. It should also answer the question which forms its title, and discuss the problem of classification.

Velký Roudný is the largest eruption cone in the area. Its summit reaches 780 m above sea level. The total area consisting of the products of volcanic activity covers about 10 km^2 (Geological map of Czechoslovakia). It is a typical strato-volcano formed from extrusions alternating with unconnected areas of ejected material. Ketner (1952 in Roth *et al.* 1962) and Frejková (1952) state that the cone and summit consist of ejected material. They have different grain sizes, ranging from volcanic bombs with a diameter of up to 80 cm, to fine grained volcanic ash. Ketner (1952 in Roth *et al.* 1962) considers the depression at the summit of the cone to be the remains of a crater. According to Pacák (1928), the scoria on the slopes of the hill consists of grey-brown nepheline basalt with phenocrysts of olivine and augite in a matrix of olivine, augite, nepheline, and basalt. Opletal (1987 in Roth *et al.* 1962) states that the geological bedrock consists of pyroclastic basaltoid at the foot of the hill, and olivine basaltoid composed of olivine, augite, plagioclase, and magnetite at the summit. Barth (1977) concludes that Velký Roudný is probably an object that extends deep into the ground – a batholite. Three flows erupted from the side of the cone (Roth *et al.* 1962): the approximately 3 km long southern flow, the approximately 5.4 km long Chřibský Forest flow, and the short northern flow. The petrographical characters of the northern flow and the Chřibský Forest flow are not known. The southern flow consists of grey-brown to grey-black porphyric basalt, which consists of phenoclysts of olivine and augite in a matrix of olivine, augite, plagioclase, and magnetite.

Profile No. 1 was taken from a site about 20 m below the summit on the steep (approx. 25°) south-west slope of the cone at an altitude of 760 m, 49°53’31” latitude, 17°31'23" longitude, in an area of mixed forest (beech, ash, spruce) on the southern flow. Profile No. 2 was opened on the foot of the cone at an altitude of 705 m on a grassy artificial terrace (49°53'24", 17°31'04"). In the past, this terrace was probably ploughland.

Both profiles were described and samples from various horizons were taken for chemical and texture analyses. Kopecky cores were taken from the andic horizons of both profiles to assess the physical characteristics (three cores from each horizon). The cores could not be taken from the bottom soil of the profiles because of the high content of skeleton. The following assessments were then carried out in the accredited laboratories of the Research Institute for Soil and Water Conservation in Prague:

– active and exchange soil reaction
– total content of C_{ox}
– contents of fulvic acids FA, humic acids HA, and humic matter HM. The FA/HA ratio was then determined
– humus colour quotient Q 4/6
– exchangeable hydrogen H^+ and sorption characteristics; maximum sorption capacity CEC, content of exchangeable bases S, effective sorption capacity ECEC, and saturation level V
– total nitrogen content N
– contents of oxalate-leachable Fe and Al
– content of free iron (dithionite according to coffin)
– overall texture analysis
– % content of PO_4^{2-} anions
– physical characteristics: volume moisture, total porosity, maximum capillary water capacity, bulk density.

Mineralogical analysis was not carried out.

RESULTS

The descriptions of the profiles were carried out according to the principles of the Taxonomic Soil Classification System of the Czech Republic (Němeček *et al.* 2001) and according to Munsel Soil Color Charts (Anonymous 1993). Analytical characteristics of both profiles are in Tables 1 and 2. Profile No. 1 is on Figure 1.

Profile 1

Steep slope below the top of the hill, forest

+4–0 cm, O: overlaying anhydromorphic horizon of litter (leaves + needles, Ln + Lv);

Figure 1. Profile No. 1.

Table 1. Analytical characteristics of Profile No. 1.

Depth (cm)	Horizont	pH/KCl	pH/H_2O	C_{ox} (%)	FK (%)	HK (%)	HL (%)	FK/HK	Q 4/6	H^+ex (mmol$^+$/100 g)	CEC (mmol$^+$/100 g)
+4–0	O	3.73	4.26	21.28	4.99	1.80	10.52	2.77	7.7	86.0	90.40
0–12	Aa1	3.56	4.40	14.51	5.90	2.09	6.99	2.82	7.6	50.0	47.66
12–45	Aa2	4.11	5.06	5.82	3.33	1.01	3.48	3.29	7.1	47.6	38.95
45–65	ABa	4.74	5.73	3.93	2.43	0.69	2.26	3.52	7.0	30.8	30.01
> 65	B/C	4.86	5.91	2.19	2.02	0.57	1.08	3.54	7.0	25.0	30.85
		base saturation (mmol$^+$/100 g)	saturation (%)	ECEC (mmol$^+$/100 g)	N total (%)	C/N	Fe_{ox} (%)	Al_{ox} (%)	Fe coffin (%)	< 0.002 mm (%)	< 0.01 mm (%)
+4–0	O	< 3.0	< 10	15.16	1.58	13.46	–	–	–	–	–
0–12	Aa1	< 3.0	< 10	14.04	0.91	15.94	0.66	1.36	0.76	8.6	23.5
12–45	Aa2	< 3.0	< 10	12.40	0.35	16.62	0.59	1.51	0.72	6.9	20.3
45–65	ABa	< 3.0	< 10	11.86	0.24	16.37	0.34	1.64	0.62	5.0	26.1
> 65	B/C	< 3.0	< 10	9.40	0.13	16.84	0.30	1.72	0.55	4.8	30.0
		0.01–0.05 mm (%)	0.05–0.25 cm (%)	0.25–2.0 mm (%)	PO_4^{2-} retention (%)	moisture (% vol.)	porosity tot. (%)	max capillar water content (%)		bulk density (g/cm^3)	
+4–0	0	–	–	–	–	–	–	-		-	
0–12	Aa1	47.1	28.4	1.0	60.0	26.66	75.98	32.40		0.54	
12–45	Aa2	36.4	40.4	2.9	60.5	30.51	67.15	33.72		0.84	
45–65	ABa	46.6	18.5	8.8	72.6	–	–	–		–	
> 65	B/C	43.7	20.3	6.0	70.0	–	–	–		–	

Table 2. Analytical characteristics of Profile No. 2

Depth (cm)	Horizont	pH/KCl	pH/H_2O	C_{ox}	FK	HK	HL	FK/HK	Q 4/6	H^+ex	CEC
				(%)						(mmol$^+$/100 g)	
0–28	Aap	5.36	6.12	5.21	1.95	1.50	2.75	1.30	7.4	17.2	31.10
28–45	Aa	5.55	6.40	5.45	1.05	0.66	1.25	1.59	6.6	13.0	27.10
45–70	ABa	5.67	6.52	3.08	0.98	0.48	0.87	2.04	6.5	11.0	27.63
> 70	B/C	5.81	6.75	1.78	0.44	0.18	0.40	2.44	6.3	9.2	21.31
		base saturation (mmol$^+$/100 g)	saturation (%)	ECEC (mmol$^+$/100 g)	N total (%)	C/N	Fe_{ox}	Al_{ox}	Fe coffin	< 0.002 mm	< 0.01 mm
									(%)		
0–28	Aap	13.90	48	20.70	0.48	10.8	1.57	0.51	2.22	8.4	27.4
28–45	Aa	14.10	52	19.04	0.50	10.9	1.58	0.54	2.17	7.8	31.7
45–70	ABa	16.63	60	19.42	0.30	10.3	1.64	0.51	2.03	7.1	33.1
> 70	B/C	12.11	57	14.28	0.16	11.1	1.51	0.49	1.89	5.6	30.2
		0.01–0.05 mm	0.05–0.25 cm	0.25–2.0 mm	PO_4^{2-} retention	moisture (% vol.)	porosity tot.	max capillar water content		bulk density (g/cm^3)	
			(%)					(%)			
0–28	Aap	28.6	37.8	6.2	55.5	–	–	–		–	
28–45	Aa	40.3	20.2	7.8	56.0	28.14	70.22	32.11		0.88	
45–70	ABa	39.3	19.9	7.7	58.3	32.14	60.13	30.20		0.90	
> 70	B/C	34.6	23.0	12.2	56.2	–	–	–		–	

0–12 cm, Aa1: brownish black 5 YR 2/1, gentle crumby structure, sandy loam, mild moistured, strongly humic, very loose consistence, skeleton 15% up to 3 cm in diameter, diffuse non-distinct transition;

12–45 cm, Aa2: black 5 YR 1.7/1, weakly crumby polyedric structure, sandy loam, strongly humic, loose consistence, skeleton 20%, 5 cm in diameter, gradual wavy transition;

45–65 cm, ABa: transition to parent material. Brownish-black 5 YR 3/1, slightly polyedric ~ non structured, sandy loam, strongly humic, loose consistence, gravel, stones and boulders 30% up to 30 cm in diameter, diffuse wavy transition;

> 65 cm, B/C: brownish – gray 5 YR 4/1, non-structured, sandy loam – loamy texture, loose consistence, skeleton + boulders > 50%, 30 cm in diameter.

Profile 2

Meadow, apparently ploughland in the past.

0–24 cm, Aap: anhydromorphic (molic?) humic horizon, brownish – black 5 YR 2/2, crumby structure, sandy loam, strongly humic, very loose consistence, mildy moistured, admixture of gravel up to 3 cm in diameter, strait distinct transition (depth of ploughing);

24–45 cm, Aa: brownish – black 5 YR 2/1, crumby structure, loamy, strongly humic, very loose consistence, moist, gravel 10%, 3 cm in diameter, gradual transition;

45–70 cm, ABa: brownish – black 5 YR 2/2,weakly crumby – polyedric structure, loamy, moist, loose consistence, skeleton content 25% – gravel and stones to 5 cm, wavy diffuse transition;

70–85 cm, B/C: brownish – gray 5 YR 3/2, non-structured, humic, weakly firm consistence, moist, loamy, stones and boulders up to 40 cm in diameter, 40%.

DISCUSSION

The diagnostic characteristics of Andosols are part of all classification systems. According to WRB-FAO 2006, the soils assigned to the Andosols class are those which have:

(a) one or more layers with andic or vitric characteristics and a total combined thickness of those horizons

– either of 30 cm or more to a depth of 100 cm from the surface and starting from a depth of 25 cm;

– or which take up 60% or more of the total thickness of the soil profile to the solid rock or cemented layer, which starts at a depth of 25–50 cm

(b) provided that the profile does not have an argic, ferralic, petroplintic, plintic or spodic horizon, with the exception of buried fossil horizons.

The WRB-FAO (2006) classification, in order to define the lower units precisely, gives a total of 18 prefix qualifiers and 20 suffix qualifiers, which specify morphological, physical, chemical, and substrate characteristics.

In WRB (2006), andic characteristics are defined very precisely and strictly. The only characteristics of both our profiles which conform to the diagnostic characteristics required for andic soils are the combined total thickness of the andic horizons (for the first profile that means Aa1 + Aa2 + ABa, for the second profile Aap + Aa + Aba), and their bulk densities. Other diagnostic characteristics (clay content, Al_{ox} + ½ Fe_{ox} > 2, phosphate retention) do not meet the criteria. The supporting characteristics which conform are colour, the FA/HA ratio, and the C:N ratio. Because the WRB (2006) classification requires the fulfillment of all the stimulated characteristics, it is possible to conclude that neither profile evaluated meets the criteria for andic properties.

The vitric horizons differ from the andic horizons because they have a lower level of weathering. The required diagnostic characteristics are also less strict. Both evaluated profiles fulfill all the criteria of the vitric diagnostic characteristics, ie: thickness, bulk density, clay content in fine earth, content, Al_{ox} + ½ Fe_{ox} >2 and phosphate retention, and also fulfill the criteria for the supporting characteristics (colour, FA:HA ratio, reaction). Only the C:N ratio conforms but partially. Neither profile meets the WRB requirements for the melanic humic surface horizon. They have the pachic characteristics typical of andosols with a molic or umbric humic surface horizons. Umbric horizon characteristics are better developed and visible in the second (grassland) profile, in which they combine with the not clear criteria of colluvial process.

We may therefore conclude that, according to the WRB (2006) system, profile No.1 (the forest profile) can be classified – because its sorption complex is saturated far below 20% – and with the use of prefix and suffix levels of classification, as a

Vitric Andosol (Dystric), Profile No. 2 (grassland at the foot of the hill) should be classified, again because its sorption complex saturation is below 50% and with the umbric and colluvic morphological features taken into account, as Vitric Umbric Andosol (Dystric, Colluvic), which is however not so conclusive. This profile appears to display the impact of long-term cultivation and the use of the land as ploughland. Because of its position, some colluvial properties are also evident.

The Slovak MKSPS classification system (Sobocká *et al.* 2000) uses criteria rather different from those of WRB-FAO (2006). It describes Andosols as soils with a melanic Aa horizon and a cambic Bva horizon from the weathering of volcanic rocks with a predominance of vitric substances. The thick, dark, humic A horizon clearly dominates and suppresses the visual characteristics of the B horizon, which, because of the diffuse transition with the A horizon (high humus content, dark colour), has rather the morphological character of the transitional A/C horizon.

According to the Slovak system, the most important characteristics of the two evaluated profiles fail to meet the andic criteria, ie: phosphate retention, content, and Al_{ox} + ½ Fe_{ox} >2%. Their bulk density and colour do meet the criteria.

The Slovak system has a concept of the melanic horizon different from WRB. The criteria of thickness and colour conform to the concept in the Slovak MKSPS, while only bulk density conforms to the undefined requirement for "some andic characteristics". The humus content is probably below the required level (> 6% as the average of all the layers, or > 4% in all horizons).

According to the Slovak system, most of the characteristics of both profiles meet the criteria for the characteristics of cambic andosol horizons: the set of horizons (Aa1 + Aa2 + ABa in the first profile, and Aap + Aa + Aba in profile No.2) display great thickness, the content of free Fe according to coffin is higher in the ABa horizons than in the B/C horizons, they have less than 75% skeleton content, the fine earth is non-carbonate, neither profile fulfills the conditions for the occurrence of the luvic, spodic, mottled, or eluvial horizons. The conditions for a higher clay content in the Aa + ABa horizons than in the B/C horizons are barely met. Balkovič (2002) points out, however, that the common type of texture analysis, especially when used to evaluate the clay content, is not entirely appropriate, because when the samples of andic soils dry out, irreversible cementation of the clay fraction takes place, and the analysis may therefore not be reliable. Likewise, the chroma criterion for the shade of colour, which should be higher in the B/C horizon than in Aa + ABa, is not met. It is possible that neither of the two described profiles was excavated deeply enough. Balkovič (2002) also proposes that the Slovak classification system should stop using its concept of the melanic horizon, because it is not compatible with the WRB concept. The same applies to the Czech classification (Němeček *et al.* 2001).

We think that both profiles should, despite certain reservations, be classified, according to the Slovak MKSPS system, as Andic Cambisols. There is no alternative in the Slovak system, because it does not define the criteria for vitric horizons.

The fundamental problem in classifying similar profiles is the fact that andic characteristics are often found in several soil horizons, which does not meet the requirement for the morphological differentiation and diagnostic function of the horizons. The Bv weathering horizons with some andic characteristics, which constitute transitional types between the cambic and andic horizons, are also problematic. That is why WRB created the concept of Vitric Andosols for the soils on young volcanic substrates with the potential for an andic process.

CONCLUSION

On the basis of the results obtained and their analysis in our discussion, we can answer the question which forms the title of this contribution in the affirmative. Andosols do indeed occur in the Czech Republic, although not in their typical form. The area they cover is undoubtedly small. According to the current research, they are limited to the tertiary volcanic ejected material in the Bruntál district and its immediate vicinity. In the Comprehensive Soil Survey (Anonymous 1967) they were still classified as Brown soils (Cambisols); on later maps, they were classified as Eutric Cambisols (Novák *et al.* 1990–1992), that is apparently incorrect.

On the basis of the current findings, we might also submit a proposal for the supplementation of the Czech Taxonomic Soil Classification System (Němeček *et al.* 2001) with lower units of the reference group of Andosols or the lower units of the soil type Andozem, respectively.

According to our proposal, the subtypes of andosols can be the following:

– Halpic Andosol: without additional diagnostic characteristics or their display. Due to the conditions in the Czech Republic this subtype appears to be hypothetical.
– Vitric Andosol: the occurrence of this subtype is probable in locations on volcanic ejected material in the Bruntál area and possibly elsewhere, too.
– Litic Andosol: with a strongly skeletal Bva and B/C horizon and a relatively thin Aa horizon. Presumably only on the summits of volcanic ejected material or on their scree slopes.
– Umbric Andosol: with humic horizon that has umbric morphological features and other umbric diagnostic criteria.
– Outside the Andosol reference group, the subtype Andic Cambisol should also be included in the classification system or, within the andosol group, in the subtype Cambic Andosol. Their differentiation is, however, problematic. We may, nevertheless, presume that it is these two profiles which will occur most frequently in the volcanic localities.

In addition, we think that the evaluation of the sorption complex saturation and reaction should be carried out only at the level of variety, which, of course, conflicts with the principles and concept of the Czech TKSP Classification, which makes this distinction at the subtype level.

These preliminary proposals will need, of course, to be developed further and to define the criteria and characteristics of the subtypes and lower units, thus enabling the classification within the system.

References

Amano Y. (1988): The Andisols-Entisols transition. In: Proc. 9th Int. Soil Classification Workshop. Soil Management Support Service, Washington D.C.

Anonymous (1967): Comprehensive Soil Survey of Bruntal District. Report. Maps 1:50 000, Maps 1:5 000. ESSP – Czech Academia of Agricultural Sciences, Prague.

Anonymous (1993): Munsell Soil Color Charts. Eijkelkamp, Glesbeek.

Arnold R. (1996): Keys to Soil Taxonomy. 7th Ed. USDA/NRCS, Washington D.C.

Arnold R.W. (1988): The worldwide distribution of Andisols and the need for an Andisol order in US Soil Taxonomy. Soil Management Support Service, Washington D.C.

Balkovič J. (2002): Soils with Andic Properties in Choosen Slovakia Mountains. [Ph.D. Thesis.] Komensky University Bratislava.

Barth V. (1977): Basaltic volcanos in middle part of Jeseniky Mountains. Journal for Mineralogy and Geology, **22**: 279–291.

Brady N.C., Weil R.R. (2002): The Nature and Properties of Soils. Prentice Hall-Upper Saddle River, New Jersey.

FAO (2006): Guidelines for Soil Description. 4th Ed. FAO, Rome.

Frejková L. (1952): Contribution to knowledge of Moravian-Slezian volcanos of low Jeseniky Mountains. Journal of Nature Sciences of Ostrava Region, **13**: 315–334.

Higashi T. (1983): Characterisation of Al/Fe humus complexes in Dystrandepts through the comparision with synthetic forms. Geoderma, **31**: 277–288.

Holuša O. (2003): Finding of Andosol at National Nature Relic Great Roudny (Low Jeseniky Bioregion). Study of Beskyd Museum, Frýdek-Místek, Natural Sciences No. 3, 221–224.

HonnaT., Yamamoto S., Matsui K. (1988): A simple procedure to determine melanic index that is useful for differentiating Melanic from Fulvic Andisols. Icomand, Intern. Committe on the Classification of Andisols, New Zealand Soil Bureau, Lower Hut.

Hraško *et al.* (1991): Morphogenetic Soil Classification System of Czecho-Slovakia. RISC Bratislava.

Juráni B., Balkovič J. (2007): Soils of volcanic regions in Slovakia. In: Soils of Volcanic Regions in Europe. Springer, Berlin, 82–102.

Němeček J., Smolíková L., Kutílek M. (1990): Pedology and Paleopedology. Academia, Prague.

Němeček J. *et al.* (2001): The Czech Taxonomic Soil Classification System. Czech Agricultural University, Prague.

Novák P. *et al.* (1990–1992): Synthetic Soil Map of the Czech Republic 1:200 000, Sheet B5 – Opava, Ministry of Agriculture, Prague.

Pacák O. (1928): Basalts of Jeseniky Mountains and Closed Region. Journal of Royal Czech Society of Sciences, Prague, No. 4, 172–186.

Roth Z. *et al.* (1962): Explanation to Overview of Geology, Map of CSSR 1:200 000, Sheet M-33-XXIV, Geofond Prague.

Shoji S., Otowa M. (1988): Distribution and significance of Andisols in Japan. In: Proc. 9th Int. Soil Classi-

fication Workshop. Soil Management Support Service, Washington D.C.
Shoji S., Nanzyo M., Dahlgren R.A. (1993): Volcanic ash soils: genesis, properties and utilization. Developments in Soil Science, No. 21, Elsevier Amsterdam.
Shoji S., Nanzyo O., Dahlgren R. A., Quantin P. (1996): Evaluation and proposed revisions of criteria for Andosols in the WRB. Soil Science, **161**: 604–615.
Sobocká J. *et al.* (2000): Morphogenetic Classification System of Soils of Slovakia. RISC Bratislava.
Soil Survey Staff (1999): Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Agricultural Handbook 476, USDA Washington D.C.
Stejskal J. (1958): Agricultural Geology. Czech Academy of Agricultural Sciences, State Agricultural Publishing, Prague.
Šály R. (2000): Soil of Nature Protected Region – Biospheric Reservation Polana. RISP Zvolen – Bratislava.
Takahashi T., Nanzyo M., Shoji S. (2004): Proposed revisions to the diagnostic criteria for andic and vitric horizons and qualifiers on Andosols in the WRB for Soil Resources. Soil Sci. Plant Nutr., **50**: 431–437
Tan H.K. (1984): Andosols. Van Nostrand Reinhold, New York.
WRB-FAO (1998): World Reference Base for Soil Resources. 1st Ed. ISRIC-FAO, Rome.
WRB (2006): World Reference Base for Soil Resources, 2nd Ed. ISRIC-FAO, Rome.

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