Acta Universitatis Sapientiae
Agriculture and Environment, **3**, (2011) 110–121

Andosols of the East Carpathian volcanic range

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Manuscript received April 20, 2011; revised May 21, 2011; accepted May 25, 2011

Abstract. According to WRB (World Reference Base for Soil Resources) [39] andosols are dark soils with high organic matter content formed on young volcanic rocks. Their characteristics are determined primarily by allophanes, imogolite, ferrihydrite and Al/Fe-humus complexes. Their macro-structure is very loose with low value for volume mass, thixotropy, high cation exchange capacity and phosphorous retaining capacity are characteristic for them.

Geographical distribution, upper and lower limits of andosols in Romania are still to be made clear. Limited publications give controversial data in relation to the latter. Their appearance on maps published in recent years is controversial and hard to interpret especially in the cases of the Harghita and the Gurghiu Mountains.

According to Romanian pedological literature andosols can be found above 1200 m a.s.l., however, on soil maps of the scale 1:200.000 [35, 36, 37] covering the Călimani-Gurghiu-Harghita volcanic chain as well they extend up to only 1500 m.

Researches carried out in the region detected initial spodosolization processes in soil profiles described in the Harghita and Călimani Mountains that, however, cannot be corresponded to the current criteria for andosols set by the WRB.

Primary aim of our research therefore is to make clear, at least partially, these two issues.

In order to study the two aspects presented above, detailed soil investigation was carried out along a reference profile between the heights of 1780 m and 700 m a.s.l. in our study area. Ten major profiles are located so that the most characteristic landforms are crossed. Apart from the major profiles a control profile network was set as well. Disturbed and undisturbed soil samples taken along the major profiles were analysed in the laboratory.

Based on the results, it can be stated that specific andosols (non allophonic aluandic soils) can be found in the Eastern Carpathians. In most of the studied profiles traces of spodosolization (podsolization) can be detected. This is suggested by laboratory analyses revealing the inwash of Al/Fe humus complexes not mention in literature elsewhere only in Romania. As characteristics of andosols are present in all of the studied profiles, joint activity of two processes, andosolization and podsolization or spodosolization can be suggested. It is only a conjecture that the process runs from andosolization towards podsolization, obtaining proofs, however, requires further research.

Based on the above we suggest the introduction of the above soils into the WRB system under the name Spodic andosol or Podzic andosol at one of the lower levels of the Andosoil soil type.

The results do not support the limitation of andosols in the narrow height section between 1200 and 1500 m a.s.l. as seen on Romanian soil maps, they shall be corrected.

Keywords: pyroxene andesite, thixotropy, andosolization, aluandic soil, Spodic andosol, Podzic andosol

1 Introduction

According to WRB (World Reference Base for Soil Resources) andosols are dark soils with high organic matter content formed on young volcanic rocks. Their characteristics are determined primarily by allophanes, imogolite, ferrihydrite and Al/Fe-humus complexes. Their macro-structure is very loose with low value for volume mass, thixotropy, high cation exchange capacity and phosphorous retaining capacities are characteristic for them. Due to their high organic matter and amorphous clay mineral content they are suitable for binding heavy metals, micro-elements (cations and anions) and organic

components. Their detailed analysis is generally performed in countries where volcanic activity is currently experienced or where very young volcanic rocks can be found. Professionals in the Carpathian Basin started the studying of andosols in the 1970s. Detailed studies have been published by Slovakian scientists recently [4, 5, 6], however, scientific attention has been drawn to these soils nowadays in Hungary as well, even though natural conditions in Hungary are not the best for andosol formation. Papers related to andosols were published first in Romania in 1974 [8]. The category andosol appeared first on a soil map in 1979 [17], however, the Research Institute for Pedology and Agrochemistry (Institutul pentru Cercetări de Pedologie şi Agrochimie - ICPA) uses the category on maps published only after 1987. Before these soils were regarded to be acid brown forest soils, podsol brown soils or brown podsols (cryptopodsols).

In Romania the longest, relatively young, continuous volcanic range is found comprising the western belt of the Eastern Carpathians. This is an excellent location for the forming of andosols from several aspects. Despite this only a few scientists considered them for research due to their difficult accessibility. Romanian andosols were studied in detail only by Vasu A. [29, 30, 31, 32], Perepeliţă [23, 25] and Perepeliţă and al. [24]. They detected initial spodosolization processes in soil profiles described in the Harghita Mountain that, however, cannot be corresponded to the current criteria for andosols set by the WRB. This has to be made clear by future research. Geographical distribution, upper and lower limits of andosols in Romania are still to be made clear. Limited publications give controversial data in relation to the latter. Their appearance on maps published in recent years is controversial and hard to interpret especially in the cases of the Harghita and the Gurghiu Mountains. Primary aim of our research therefore is to make clear, at least partially, these two issues.

Environmental conditions determining the formation of andosols

Geological and relief conditions

The 160 km long and 60 km wide youngest western range of the Eastern Carpathians is composed of andesite tuff, breccia and andesite lava rocks formed by intense volcanic activity at the end of the Tertiary extending into the Pleistocene. The southern youngest segment of the longest volcanic chain in Europe can be dissected into three major units: Călimani Mountains, Gurghiu Mountains and Harghita Mountains. Our study area, the Saca and Harghita

Mădăraşului forms the central block of the central unit, and the northern block of the southern one It is composed mainly of lava rocks. The outer gentler slopes of the shield-like volcano extending across 20 km are dissected radially by rivers. Volcanic cone of the 1780 m high Saca Mare and the 1800 m high Harghita Mădăraşului are composed of pyroxene andesite lava flows with subordinate amount of pyroclasts. The central crater cones are encircled by an upland of volcanic agglomerates at the height of 850-1000 m.

According to the K-Ar age determination of three independent laboratories – [20, 22, Seghedi et al. (in print) – the age of the rocks is around 7.2 million years, i.e. upper Pontus – Dacian [28].

The entire mass of the Gurghiu Mountains, including the Saca Mare as well can be regarded rather uniform considering both petrology and geochemistry. Apart from some small andesite-basalt and dacite sections the whole mountain is composed of pyroxene andesite. Material of the rock consists of 29-32% phenocrysts, its major part is amorphous glassy matrix. Based on its chemical composition it is a typical K-calcalkaline rock (Table 1).

Table 1: Chemical composition of the pyroxene andesite

	%
SiO_2	57.00
Al_2O_3	17.64
Fe_2O_3	4.19
FeO	3.18
MnO	0.15
MgO	3.52
CaO	7.35
K_2O	1.22
Na_2O	3.53
TiO_2	1.11
P_2O_5	0.2
H_2O^+	0.53
S	0.17
Total	99.80

Presence of volcanic glass and feldspars together with great amount of silicon and aluminium – if climatic conditions are suitable – helps andosolization in the course of soil formation (characteristic for volcanic rocks).

Climatic conditions

Specificly cool, humid climate mountain climate characterizes our study area. Annual precipitation varies between 800 and 1200 mm depending on height. At the Bucin meteorological observatory at the height of 1280 m 20 years average of annual mean temperatures is 3.8°C while the 20 years average of annual precipitation is 951 mm. These climatic data are perfect for andosol formation.

Vegetation

Vegetation in the lower region between 600-1000 m is composed mainly of beech- Fagetum carpaticum (Soó 1935). After the beech mixed spruce transitional belt the bilberry spruce forest – Piceetum myrtilletosum – is dominant. Above the forest line on the gentle sloping plateau of Mezőhavas between 1650 and 1780 m almost completely continuous dwarf mountain pine – Pinus mugo – is found. One-or-two sporadic spruce may still occur. Herb layer consists of bilberry – Vaccinium myrtillus, bog bilberry – V. uliginosum, rough small-reed – Calamagrostis arundinacea, red fescue – Festuca rubra, mat- grass – Nardus stricta. Due to low temperatures decay in the soil is slow producing large amount of raw humus.

Forests are interrupted by clearings and mountain pastures of various sizes. In the narrow valleys of the lower region vegetation inversion is frequent: beech is above pines; pine forests may extend down to 800 m. Shrub layer of the woodlands is composed of a few species. Characteristic species are blackberry, raspberry, germander meadowsweet, black-berried honeysuckle and bilberry. Cover of the grass level reaches not 50%. Developed moss level is also formed in the wet, shaded spruce forests with closed canopy.

Soil of areas covered by forests is mostly undisturbed; covered primarily by 5-8 cm thick fresh and decaying fallen leaves that were not mixed with the mineral layer and by raw humus. In the case of traditional forestry, areas of forest clearings show disturbed soils, however, significant soil degradation was not experienced. At these locations, felling plants appear right after the termination of forestry indicating the first step of forest regeneration. Herbs appearing after felling are generally high, requiring light and enduring disturbance. Most of them have tiny seeds that are moved by wind. Shrubs also start to grow. Raspberry is generally amongst the first ones to appear together with red-berried elder (Sambucus racemosa), goat willow (Salix caprea), rowan (Sorbus aucuparia) and blackberry species. Amongst the herbs of the initial stages

rosebay willow herb (Chamaenerion angustifolium), Alpine ragwort (Senecio nemorensis subsp. fuchsii) are the most frequent forming continuous cover with associated grama-grass species. This vegetation provides the source of high amount of organic carbon accumulation characteristic for andosols.

2 Material and methods

According to Romanian pedological literature andosols can be found above 1200 m a.s.l., however, on soil maps of the scale 1:200000 covering the Călimani-Gurghiu-Harghita volcanic chain as well they extend up to only 1500 m. In higher regions only brown podsols (podzoluri brune) and podsol brown soils (soluri brune feriiluviale podzolice) are depicted on the maps of the Pedological and Agrochemical Research Institute published in 1988 and 1994 (Harta Solurilor României, scara 1:200000, foile 11 Bistriţa 1994, 12 Gheorgheni 1988, 20 Odorhei 1994).

Perepelită et al. [24] limits the conditions of andosol formation to the narrow belt between 1000 and 1300 m in the Harghita.

Our observations revealed that both the upper and lower limits of andosol distribution mentioned above need revision. In order to study the issue detailed soil investigation was carried out along a reference profile between the heights of 1780 m and 700 m a.s.l. in our study area. Ten major profiles are located so that the most characteristic landforms are crossed. Apart from the major profiles a control profile network was set as well. Disturbed and undisturbed soil samples taken along the major profiles were analysed in the laboratory of the Department of Soil Science and Agricultural Chemistry, Szent István University, Gödöllő. Thin-sections were analysed in the Pedological and Agrochemical Research Institute (Institutul de Cercetări pentru Pedologie şi Agrochimie).

Apart from analyses for determining basic characteristics the following analyses were performed in order to investigate ando characters:

Volume mass (Ts) (g/cm^3)
NaF reaction $pH_{(NaF)}$
Organic C content Corg (in mass%);
Phosphate retaining capacity (P_{ret}%);
Oxalate reaction (Al_o; Fe_o; Si_o);
Dithionitic extraction (Al_d; Fe_d; Si_d);
Pyrophosphate extraction (Al_p; Fe_p; Si_p).

3 Results and discussion

In situ measurements and laboratory analyses – Ts ¡ 0.9 g/cm^3, Pret ¿ 70%, (Al_o+0.5Fe_o) $\geq$ 2, pH_{NaF} $\geq$9.4 – prove andosol character of the soil formed on pyroxene andesite in the region of the Gurghiu Mountains above 950-1000 m up to the 1780 m top of Saca Mare (Table 2). Distribution of andosols is the same as that of beech mixed spruce, pure spruce and dwarf mountain pine and mountain pastures.

Table 2: Soil parameters relevant for andic properties

Section hight a.s.l.	Layer	Depth cm	pH_{NaF}	C_{org}	Si_o	Al_p/Al_o	Al_o+1/2 Fe_o%	Ts g/cm^3	P_{ret} %	Andic properties
1775	Ah ABw	5-17	8,9	13.0	0,07	1,18	2,00	0,51	82	+++
	Bw	17-21	10,1	10,1	0,13	1,20	3,84	Nd	94	++++
		21-35	9,7	6,8	0,15	1,20	4,05	0,62	94	++++
1500	Ah	0-15	7,5	14,63	0,11	1,03	1,10	Nd.	68	?
	ABws	15-18	8,0	10,06	0,08	1,33	2,68	Nd.	92	++
	Bws	18-26	10,7	10,37	0,12	1,11	3,14	0,46	95	++++
	Bw	26-60	10,6	2,47	0,04	0,48	2,08	0,86	83	++++
1250	Ah	4-14	8,2	17,2	0,06	1,38	1,27	0,35	71	++
	Bws	14-21	10,8	8,6	0,19	1,28	3,58	0,50	94	++++
	Bw	30-50	10,2	2,8	0,43	0,57	2,65	0,65	85	++++
1050	Ah	5-20	9,3	22,8	0,18	1,03	1,90	0,31	83	++
	Bws	20-25	11,3	9,8	0,21	0,44	5,74	0,40	85	++++
	Bw	25-45	10,2	3,8	0,07	0,45	3,33	0,67	90	++++
850	Ao	0-20	7,6	4,2	0,06	0,60	0,67	Nd.	36	–
	AB	20-30	7,6	2,3	0,06	0,61	0,62	Nd.	31	–
	Bw	30-60	7,7	0,08	0,08	0,50	0,54	Nd.	32	–

Andic properties: Al_o+1/2Fe_o% $\geq$ 2; P_{ret} >70%; pH_{NaF} $\geq$ 9,4; Ts < 0,9
Strength: ++++ (4/4), +++ (4/3), ++ (4/2)

It is a special characteristic that transition towards lessivage brown forest soils or acid brown forest soils is very sharp at the lower boundary of andosols. A transitional ando-like acid brown forest soil (andic acrisol or andic cambisol) belt is missing. If it would be present it was so narrow that could be detected only by a very detailed in situ survey. One explanation for this can be that lava rocks are replaced by pyroclasts at this height that mix with large amount of non igneous material.

Lower limit of andosol distribution is indicated by the rapid decrease (by 5-6 times) of organic carbon and humus.

Although older volcanic rocks disintegrate easier weathering is markedly stronger in the case of soils in the Gurghiu Mountains compared to andosols

on rocks of similar age in other landscapes of the World. This is verified by the high values of aluminium and silicon determined by oxalate extraction.

Although the current soil cover was formed entirely in the Holocene it has to be noted that prior to soil formation in the Holocene periglacial conditions "prepared" the rocks for soil formation disintegrating and weathering the surface rocks of the volcanic chain of Transylvania.

It is interesting that no clear difference can be detected in the intensity of ando characters related to height despite the almost 1000 m height difference between the lowermost and uppermost parts of the study area. Ando characters appear strongest in the ABw and Bw horizons of all studied profiles.

Nanzyo et al. [21] separated two types of andosol environments considering active aluminium: non allophanic when Al_p/Al_0 gives values between 0.8 and 1.0, and allophonic when this ration is between 0.1 and 0.4. Considering this, soils of the Gurghiu and Harghita Mountains are non allophanic andosols. This is also proved by the low pH value and high organic matter content of our soils. These make amorphous clay minerals subordinate and Al-humus complexes dominant. Also based on the low pH values and high organic matter content (Table 2) together with silicon determined by oxalate extraction and Al_p/Al_0 ratio soils of the Gurghiu and Harghita Mountains can be regarded as aluandic soils.

In the course of in situ analysis a barely detectable spodic (podsol) horizon was found in some of the andosol profiles. Laboratory analyses also supported the presence of this horizon as $Al_0+0.5Fe_0$ content increased suddenly in layer ABw or/and Bw below layer A. Based on these -ü although WRB do not recognise it -ü we consider the introduction of the term spodic andosol justified classifying them into the sub-units of andosols. Initial spodosolization processes were detected by Conea and Ghinea [8] and Perepelită et al. [24] in soils of the Gurghiu Mountains and the Harghita respectively. Comprehensive clearing of the issue justifies the continuing of in-depth research.

4 Conclusions

On the pyroxene lava flows of the Gurghiu Mountains andosols form dominantly the soil cover from the elevation of 950-1000 m a.s.l. up to the highest point of Saca Mare (1780 m). This coincides to the distribution of beech mixed spruce, spruce and dwarf mountain pine.

At the lower limit of andosols the soil turns suddenly to acid brown forest soil without a transition belt where the brown forest soil would have any ando

character. Here the rapid decrease of organic carbon and humus quantity is detected in the soil profiles while the volume mass of the soils increases from 0.3-0.6 g/cm^3 to 1 g/cm^3. Based on high organic matter content, low pH_{H2O}, relatively low value of Si_0 and large quantity of aluminium forming complexes with organic acids, non allophonic aluandic soils prevail in the Gurghiu Mountains.

Based on the results, it can be stated that specific andosols can be found in the Eastern Carpathians. In most of the studied profiles traces of podosolization (podsolization) can be detected. This is suggested by laboratory analyses revealing the in-wash of Al/Fe humus complexes not mention in literature elsewhere only in Romania [8], [24], [32]. As characteristics of andosols are present in all of the studied profiles, joint activity of two processes, andosolization and podsolization or spodosolization can be suggested. It is only a conjecture that the process runs from andosolization towards podsolization, obtaining proofs, however, requires further research.

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