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FRAGIPAN HORIZON IN ALBELUVISOLS OF THE CARPATHIAN FOOTHILLS

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Within the Carpathian Foothills area on carbonateless loess-like deposits occur, Luvisols prevail. Many of them have developed a very specific fragipan horizon that occurs between luvic and argic horizons. Soils where luvic horizon penetrates argic horizon forming albeluvic tonguing were called Albeluvisols. There was a possibility of the soil profile investigation both in horizontal and vertical sections. The fragipan horizons show very high bulk density that is connected to accumulation of a considerable amount of clay fraction. Very characteristic for fragipan horizon is the presence of clay coatings and clay infillings in prisms and clay depletion zones along vertical fissures. Clay coatings and clay infillings are rich in iron oxides.
Keywords: fragipan horizon, lessivage process, Albeluvisols, loess-like deposits, Carpathian Foothills

Introduction. Within the Carpathian Foothills Luvisols prevail. Luvisols were formed on several metres deep loess-like deposits. Haplic Luvisols and Stagnic Luvisols are dominant soil units in the region [Skiba, 1995, Skiba et al., 2003]. Carbonateless loess-like deposits and moderately humid climate result in lessivage processes. In some places Albeluvisols occur. In such soils fragipan horizon occurs. Fragipan horizon is a subsurface horizon, which can be characterised by higher bulk density than horizons above, extremely hard dry clods and considerably moist consistence. This horizon has less than 0.5% of organic carbon and very slow rate of water oozing [WRB 2006]. A very characteristic feature of fragipan horizons in the investigated soils is the presence of albeluvic tonguing between luvic and argic horizons.

Genesis of the fragipan horizon is connected to the genesis of argic horizon broken during dessication. This is connected to the shrinking of clay minerals and the separation of clods. Separated clods form very characteristic polygonal patterns (Phot.1.). White colour of the material in tongues is the effect of precipitation infiltrating deep into the soil profile. Precipitation washes off iron oxides, clay minerals and iron-clay cutans. Fragipan horizon inhibit infiltration of water, which causes stagnic colour pattern in the surface horizon. In the luvic horizon vast amount of iron and iron-manganese nodules is the evidence of stagno-gleyic properties.


Phot. 1. Fragipan horizon in Brzezie.

Aims and methods. The aim of this paper is the characterisation of the fragipan horizon in two Albeluvisols in the western part of the Carpathian Foothills (Fig. 1.). The first profile was localised in the Skawa Valley (Mucharz profile) and the second one in the north part of the Wielickie Foothills (Brzezie profile). The observations and investigations were carried out in a large archeological site where it was possible to investigate soil profiles in horizontal and vertical sections. Loess-like deposits are the parent material of

the investigated soils . Mean annual temperature and precipitation are 6-8°C and 700-900 mm, respectively. The samples have been collected from each genetic horizon and also from illuvial tongues and prisms. Standard analysis as well as mineralogical and micromorphological studies have been done. Kubiena's boxes were used to collect undisturbed samples for micromorphological observations and analyses and Kopecky's cylinders for physical properties analysis (especially bulk density and porosity). Mineralogical composition was determined by X-ray diffraction.

Results and discussion. Profile of the Albeluvisol from Mucharz is 260cm deep and its morphology is as follows: A-AEetg-Eetg-Eet-Bx-B1t-B2t-BtC-C. Texture of each horizon is silty loam. In the whole profile silt fraction prevails (from 50% in B2t horizon to 69% in A horizon). The content of clay fraction (<0,002mm) is between 14% in the humus horizon and 23% in the fragipan horizon. The content of sand fraction varies between 17% in A horizon and 28,5% in B2t horizon. Profile of the Albeluvisol from Brzezie is 180cm deep and its morphology is as follows: Ap-AE1et-AE2et-Eet-Bx-B1t-B2t. In this case, texture of all the soil horizons is also silty loam. This profile shows the dominance of silt fraction (70-80% in each genetic horizon). The content of clay fraction is 15% in the surface horizon, in the luvic horizon - 10% and in the fragipan and argic horizons - 21-22%. Each horizon contains very small amount of sand fraction (5-11%). Such texture is connected to the parent material and to the lessivage process, which moves colloidal fraction into argic horizon. The soil organic matter and organic carbon content of investigated soils is very low (Table 1.).

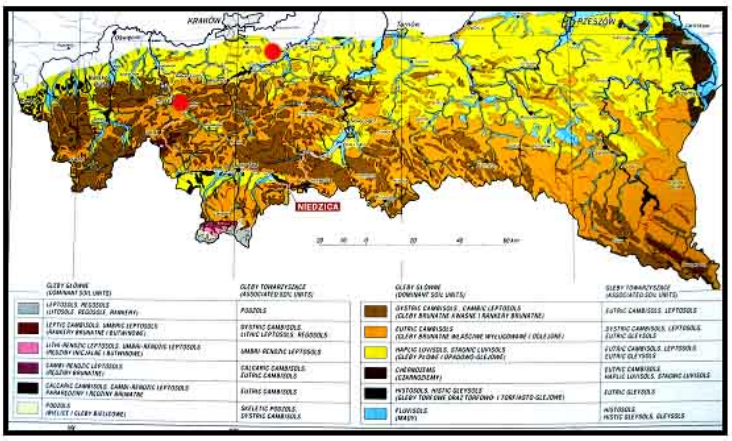


Fig. 1. Localization of the investigated soils

1. Some chemical properties of the investigated soils

Mucharz profile		pH [H_2O]	pH [KCl]	C_{org} [%]	Organic matter [%]
Horizon	**Depth [cm]**				
A	0-27	5.2	4.3	0.6	1.1
AEetg	27-40	5.3	4.2	0.1	0.2
Eetg	40-70	6.7	6.2	0.1	0.1
Eet/Bx	70-117	5.1	3.9	0.1	0.1
Bx	117-150	5.1	3.9	0.1	0.1
B1t	150-170	6.3	5.4	0.1	0.1
B2t	170-200	4.9	4.0	0.1	0.2
BtC	200-210	5.2	4.0	0.1	0.1
C	210-260	5.1	4.0	0.1	0.1
Brzezie profile		**pH [H_2O]**	**pH [KCl]**	**C_{org} [%]**	**Organic matter [%]**
Horizon	**Depth [cm]**				
Ap	0-25	5.3	4.38	1.1	1.9
AE1et	25-40	5.4	4.46	0.7	1.2
AE2et	40-58	5.4	4.50	0.7	1.2
Eet	58-70	5.4	4.67	0.2	0.3
Bx	70-95	5.1	4.04	0.1	0.2
B1t	95-115	5.4	4.21	0.1	0.1
B2t	115-180	5.9	4.65	0.1	0.1

Surface horizons contain maximum organic carbon value and it is about 1% (content of organic matter is 1,7-1,9%). Humification and mineralisation of the soil humus are very advanced. Bulk density and porosity of the soil material are connected to texture and the organic matter content. Bulk density of the profile from Mucharz ranged from 1,5Mg/m^3 to 1,8Mg/m^3 and in the profile from Brzezie it was very similar (1,4Mg/m^3-1,7Mg/m^3). The lowest values of bulk density in both profiles occur in the humus and luvic horizons what is connected to the highest organic matter content and dislocation of colloidal fraction. In those horizons porosity is the highest and it ranges from 35% in the Mucharz profile to 40-46% in the Brzezie profile. The fragipan and argic horizons show the highest bulk density (1,7-1,8Mg/m^3) and the porosity is the lowest. It is 30% in the Mucharz profile and 35% in the Brzezie profile (Table 2.).

The investigated soils can be characterised by acidic and slightly acidic reaction. Such reaction is very common in soils formed on carbonateless loess-like deposits. Values of pH(H_2O) range from 5,0 to 6,5 (Table 1.). The highest pH value occurs in Eetg horizon (from Mucharz profile) and it is possibly connected to the enrichment of the soil material with alkaline ions by lateral flow [Szymański, Skiba, 2007]. The investigated Albeluvisols do not contain carbonate and because of that intense lessivage processes take place.

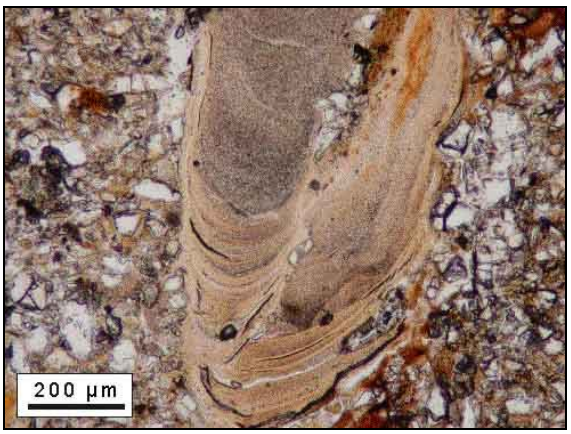
2. Some physical properties of the investigated soils

Mucharz profile		Bulk density [Mg/m^3]	Porosity [%]
Horizon	**Depth [cm]**		
A	0-27	1.50	35
AEetg	27-40	1.70	35
Eetg	40-70	1.68	35
Eet/Bx	70-117	1.73	34
Bx	117-150	1.81	30
B1t	150-170	1.76	33
Brzezie profile		**Bulk density [Mg/m^3]**	**Porosity [%]**
Horizon	**Depth [cm]**		
Ap	0-25	1.55	39
AE1et	25-40	1.50	41
AE2et	40-58	1.45	44
Eet	58-70	1.41	46
Bx	70-95	1.68	36
B1t	95-115	1.67	35
B2t	115-180	1.70	36

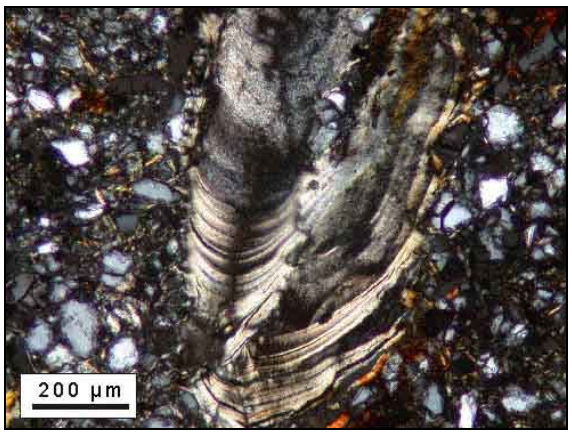
Mineralogical composition analysis indicated that the most common primary minerals are: quartz, plagioclases (mainly albite) and K- feldspars (especially microcline and sanidyne). Dioctahedral micas and secondary clay minerals such as illite and chlorite are the most abundant of 2:1 phyllosilicates. Traces of kaolinite are also present.

Micromorphological observations were carried out on thin sections of the luvic, fragipan and argic horizons. In the upper part of the Albeluvisol profiles bright, almost white luvic horizon without clay coatings occurs. Soil material is uniform and it consists of rough grains of quartz and plagioclases. Grains of K- feldspars and muscovites were also found. Upper part of the luvic horizon has very characteristic platy structure, which also occurs in Alfisols and Ultisols [Certini et al., 2007]. Iron and iron-manganese nodules are considerably numerous in this horizon. Formed in situ iron nodules (orthic iron nodules) are very common and they were formed through impregnation of the soil mass. In this horizon moved iron nodules were also observed, because of the swelling and shrinking of the soil material (disorthic iron nodules). Periodic stagnation of rainfall cause bleaching of the soil mass in the luvic horizon and also in tongues along fissures and therefore this material shows albeluvic properties. In this case, stagnic properties lead to the lessivage process forming very sharp boundary between luvic and fragipan horizons.

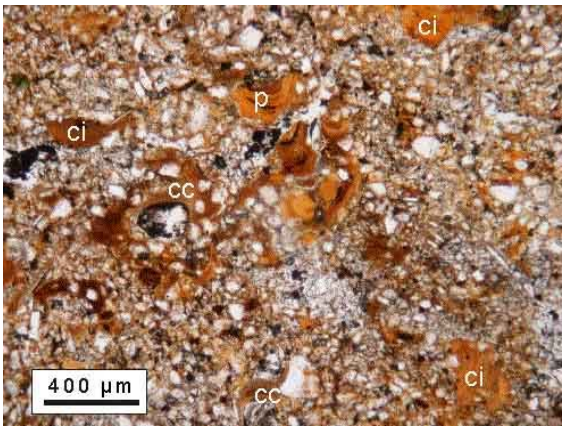
Fragipan horizon can be characterised by the occurrence of significant amounts of clay cutans, clay coatings and clay infillings with very weak pleochroism. During ageing, structures of anisotropic clay undergo mechanic deformations. Such deformations are common in the upper part of the fragipan horizon. Possibly it is connected to more intense swelling and shrinking in this part of the profile. A lot of fragments of old clay coatings (so called papules) occur here being the evidence of mechanic deformations of the soil material (Phot. 4, 5.). In this horizon very large, microlaminated silty-clay infillings were found with very good orientation of clay domains (Phot. 2, 3.).



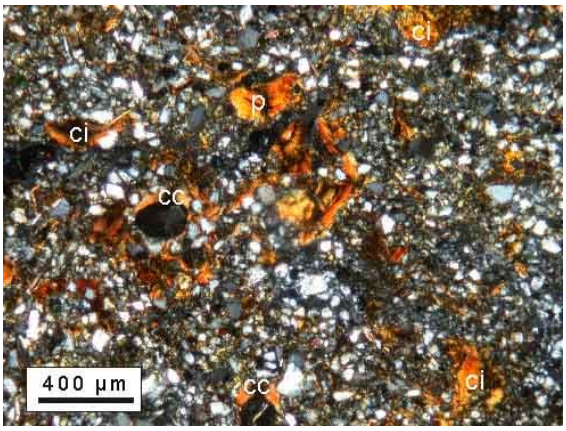
Phot. 2. A laminar clay infilling in fragipan horizon, PPL.



Phot. 3. A laminar clay infilling in fragipan horizon, XPL.



Phot. 4. Clay coatings (cc), clay infillings (ci) and papules (p) in fragipan horizon, PPL.



Phot. 5. Clay coatings (cc), clay infillings

Fragipan horizon is crossed by vertical fissures formed by dessication. Their diameters are about 500µm. Such fissures are pathways for the infiltration of rainfall into groundwater. The infiltrating water is the reason of the soil bleaching near vertical fissures. It forms zones without clay coatings and iron oxides (clay depletion hypocoatings). Clay coatings and iron oxides are accumulated in the lower part of the fissures forming several millimeters thick clay cutans. Smaller fissures, with diameters of 40-50µm, and meso i micropores are completely plugged by colloidal clay. In the upper part of the fragipan horizon formed in situ iron nodules were observed. Soil mass consists of rough grains of quartz. Small amounts of plagioclases, K- feldspars and muscovites were also observed.Material from argic horizon is very similar to the material form the fragipan horizon. Argic horizon either lacks of vertical fissures (Brzezie profile) or they are very rare (Mucharz profile). Clay coatings and clay infillings are also very common what is connected to carbonateless parent material leading to very deep illuviation of colloidal clay [Zasoński, 1983]. Formed in situ iron nodules are very rare and iron nodules moved in soil material do not occur. This can be the evidence of less intense mechanic deformations on this depth. In fragipan and argic horizons change of texture was clearly observed. There is more fine and sand fraction (rough quartz) than silt fraction what can be the evidence of the parent material of the investigated soils. Such alteration of texture is related to weathering Carpathian flysch or eolian transport from near source or both processes simultaneously [Uziak, 1962]. Material from argic horizon has massive structure and it is completely saturated by illuvial colloidal clay, which is oriented around grains (so called granostriated b-fabric) [Stoops, 2003]. Specific and well formed, microlaminated clay coatings on the walls of clods and root chanells are the evidence of the pedogenetic origin of such structures.

Conclusions.

1. Texture, reaction, content of organic matter and physical properties of the investigated soils are typical for the soil cover of the Carpathian Foothills. Texture and acidic or slightly acidic reaction are connected to carbonateless parent material.
2. The micromorphological observations and investigations confirm intense lessivage process and the pedogenetic origin of the fragipan horizon. The oxidation and reduction processes dominating over previous illuviation process and mechanic deformations soil material (swelling and shrinking) led to formation of white tongues along vertical fissures. Material from those tongues is very similar to material from the luvic horizon.
3. The occurrence of iron and iron-manganese nodules in the upper part of fragipan horizon is the evidence of periodic stagnation of precipitation water. This water causes bleaching of the luvic horizon with albic properties.
4. The water infiltrating along vertical fissures washes off the weathering products such as clay minerals, iron oxides and iron-clay cutans from the adjacent soil material and it forms typical albeluvic tongues.
5. Quartz is the main primary mineral. Soil mass consists also of plagioclases, K- feldspars and muscovite, that are transformed into secondary clay minerals such as chlorite, illite and kaolinite.

References:

1. Certini G., Ugolini F.C., Taina I., Bolla G., Corti G., Tescari F., 2007, Clues to the genesis of a discontinuously distributed fragipan in the northern Apennines, Italy, Catena, 69, s. 161-169.
2. Skiba S., 1995, Soil cover, [in:] Polish Carpathians, J. Warszyńska (ed.), Wyd. UJ, Kraków, s. 69-76.
3. Skiba S., Drewnik M., 2003, Map of soils of the Polish Carpathians, Roczniki Bieszczadzkie, 11, s. 15-20 (in Polish).
4. Stoops G., 2003, Guidelines for analysis and description of soil and regolith thin sections, SSSA, Madison, USA.
5. Szymański W, Skiba S., 2007, Genesis and significance of the fragipan horizon in the Albeluvisols of the Carpathian Foothills, Roczniki Bieszczadzkie, 15, s. 267-284 (in Polish).
6. Uziak S., 1962, The problem of the typology of some Luvisols of the Carpathian Foothills, Annales UMCS, Sec. B, s. 1-60 (in Polish).
7. WRB 2006. IUSS Working Group. 2006. World Reference Base for Soil Resources. 2nd edition. World Soil Resources No 103. FAO, Rome.
8. Zasoński S., 1983, Main soil processes on loess-like deposits of the Wielickie Foothills, Roczniki Gleboznawcze, XXXIV, 4, Warszawa, s. 123-159 (in Polish).

ФРАДЖІПЕНОВИЙ ГОРИЗОНТ В АЛЬБЕЛЮВІСОЛЯХ КАРПАТСЬКИХ ПЕРЕДГІРЬ

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В межах Карпатських передгірь на карбонатних лесоподібних відкладах превалюють лювісолі. У багатьох з них утворився дуже специфічний фраджіпеновий горизонт, який розміщується між лювіковим та арджіковим горизонтами. Ґрунти, в яких лювіковий горизонт проникає в арджіковий горизонт, формуючи альбелювікові язики, називаються альбелювісолями. Фраджіпеновий горизонт характеризується дуже високою щільністю, яка пов'язана з акумуляцією значної кількості глинистої фракції. Характерними для фраджіпенового горизонту є наявність глинистих плівок і згустків у призмах та збіднених глиною зон вздовж вертикальних тріщин. Ці новоутворення збагачені оксидами заліза.
Ключові слова: фраджіпеновий горизонт, лесиваж, альбелювісолі, лесоподібні відклади, Карпатське передгір'я.