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DEVELOPMENT OF SOILS ON PARAGNEISS AND GRANITE IN THE SOUTHEASTERN PART OF BOHEMIA

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ABSTRACT

This study presents data about the effect of parent material on the intensity of processes that lead to the formation of a cambic subsurface horizon. The study was performed in the Voděradské bučiny National Nature Reserve with granite bedrock and in Humpolec with paragneiss bedrock. Representative soil profiles in the southeastern part of Bohemia were characterised on a macroscale level based on macromorphological description, particle size distribution, chemical, physical and soil organic matter properties. On the basis of the values of organic carbon and bulk density, the stock of soil organic matter was calculated in the upper 25 cm of soils. A more detailed characteristic of soil cover employed micromorphological and X-ray diffraction analyses. The results revealed differences in the formation of the cambic horizon on different types of parent material. The main soil forming process responsible for the cambic horizon is more intensive at localities with paragneiss bedrock.

KEYWORDS: parent material, cambic horizon, mineralogy, micromorphology, reserves of soil organic matter, soil formation

INTRODUCTION

Parent material is a starting point for the process of soil formation. The role of parent material in soil development can be studied within a scheme of the same soil type on different parent materials or different soil types on the same parent material. Soil development in the Czech Republic is predominantly connected with a high diversity of parent materials. Soils with a cambic horizon on different parent material cover 45.1 % of agricultural land and 53.4 % of forest land (Kozák et al., 2010).

Cambisols occur in all temperate and hydric conditions. Climate and parent materials are largely reflected in the intensity of the development of the cambic horizon. Most studies have focused on mineralogy of soils on granitic bedrock (Tardy et al., 1973; Sirový, 1974; Taboda and Garcia, 1999). Research on soil development on gneiss has been performed by Němeček (1974). Data on the mineral composition of soils with the cambic horizon developed on calcareous sandstone, paragneiss and orthogneiss were obtained by Žigová et al. (2010).

The purpose of this study is to compare the development of Cambisols on granite and paragneiss in conditions of natural and agricultural landscape on the basis of a broad range of analyses from macroscale to microscale level.

MATERIAL AND METHODS

The study area of Humpolec is located 102 km to the southeast of Prague. This locality lies in the area with average annual precipitation of 589 mm and average annual temperature of 7.0 °C. The Moldanubian Zone dominated by metamorphic and igneous rocks is typical for this region. Chlupáč et al. (2002) described three groups of metamorphites. Tectonostratigraphy of the Moldanubian Zone *sensu stricto* is divided into the Gföhl, Drosendorf and Ostrong ("Monotonous Series") units. The Monotonous Series with biotite, biotite–muscovite and biotote–sillimanite paragneiss is typical for the study area. Near the contact with the Variscan granitic bodies, the paragneisses contain frequent cordierite. Data about the soil structure stability near the selected location were published by Kodešová et al. (2009). Soil conditions of this area are characterized on the basis of representative soil profiles Humpolec L and Humpolec PP.

The National Nature Reserve of Voděradské bučiny is located 30 km to the east of Prague. Climatic conditions of this area are characterised by average annual precipitation of 635 mm and average annual temperature of 7.3 °C. This locality is situated in the northernmost part of the Central Bohemian Plutonic Complex whose youngest part is the Říčany granite. Palivcová (1965) and Němec (1978) described the mineralogy of granites as a monotonous but also structurally variable. Biotite of the Říčany granite (monzogranite) is often chloritized, and its feldspars are sometimes argillized or sericitized with grain size usually in the range 0.1–4 mm. Xenocrysts are composed of orthoclase and reach 2–3 cm in size. The average grain size of the Jevany granite (syenogranite) is 0.4 mm. Biotite grains in this type are sparsely distributed and reach a maximum size of 1 mm. Some aspects of weathering of the Říčany granite and soil formation with the occurrence the Bw and Gr horizons were described by Minařík et al. (1998). Soil organisms such as micromycetes (Řepová, 1983) and soil and moss testate amoebae (Balík, 2001) were studied in the territory of the Voděradské bučiny National Nature Reserve. Soil cover of this locality is described from representative soil pits LP 35 and LP 36.

Selection of soil profiles was guided by a soil survey with a single gouge auger. The coordinates of soil profiles are given in the WGS 84 system; they were taken by GARMIN eTrex Summit. Soil profiles were excavated down to the Cr horizon. All samples were collected from soil horizons in soil pits. Morphological description and horizon designation was done according to Jahn et al. (2006). Individual soil profiles were classified according to the World Reference Base for Soil Resources (IUSS Working Group WRB, 2007). Colors were identified using the Munsell Soil Charts (2000).

Samples for micromorphological analyses were prepared from oriented aggregates impregnated with a polymer resin Epofix. The thin section was examined with the polarization microscope OLYMPUS BX51 with the digital camera DP70 using the Deep Focus 3.0 software. The terminology of Stoops (2003) was used for the description of thin sections.

Physical properties such as moisture, maximum capillary capacity, bulk density, particle density and porosity were measured in undisturbed core samples. Metal cylinders 100 cm^3 in volume were pressed into the soil and measured using the standard method (Dane and Topp, 2002).

The particle size distribution, chemical properties and characteristics of soil organic matter except of hot–water extractable carbon were performed using standard methods (Valla et al., 2002). Particle size distribution was determined using the pipette method. The pH values were measured in distilled water and in 1M KCl solution with a SenTix21 electrode using a soil:solution ratio of 1:2.5. Cation exchange capacity and exchangeable cations were determined using the Mehlich method. Organic carbon was determined by wet combustion with a mixture of potassium dichromate and sulphuric acid and total nitrogen using the Kjedahl method. Hot–water extractable carbon was done by Ghani (2003) with a minor modification by Krejčová (Žigová et al., 2007).

Mineral composition was studied in the fraction of <0.001 mm. Mineralogy of individual soil horizons was analysed using X–ray diffraction. Samples were prepared based on the methodology of Jackson (1975). Prior to the X–ray analysis, soil organic matter was removed by 30 % H_2O_2. The samples were then washed four times with distilled water. Clay fraction was obtained using a sedimentation method, and oriented samples were prepared by carefully pipetting the clay suspension onto a glass slide and allowing it to dry at ambient temperature. Specimens were analysed in natural state, then saturated for four hours in ethylene glycol at 80 °C and heated at 550 °C for 4 hours. X-ray diffraction spectra were obtained on a Philips X'Pert diffractometer PW3020 equipped with CuKα radiation, under a voltage of 40 kV and intensity of 55 mA. The XRD patterns were recorded at a goniometric shift 1 $^{o}.min^{-1}$ 2Θ. Semiquantitave values were calculated by K. Melka (oral information) based on the height of individual mineral basal peaks using correction coefficients.

RESULTS AND DISCUSSION

MACROMORPHOLOGICAL CHARACTERISTICS OF SOIL PROFILES

Four soil profiles located in the southeastern part of Bohemia and its main macromorphological properties were studied.

Humpolec L

Elevation: 506 m above sea level
Coordinates: 49°33´27.3´´N, 15°21´00.9´´E
Land use: permanent grass cover, herbage
Parent material: cordierite paragneiss
Ah: 0–17 cm, dark brown (10YR 3/3) moist and brown (10YR 5/3) dry, blocky subangular structure, loam texture, very friable consistence, very few rock fragments, very few small fragments of bricks, many fine roots, clear, smooth boundary
Bw: 17–49/69 cm, yellowish brown (10YR 5/6) moist and brownish yellow (10YR 6/6) dry, prismatic structure, sandy loam texture, friable consistence, common rock fragments, few fine roots, diffuse, broken boundary
Cr: 49/69–94 cm, brownish yellow (10YR 6/6) moist and very pale brown (10YR 7/4) dry, without structure, sandy loam texture, friable consistence, many rock fragments, approximately 40 % of this horizon are composed of medium-weathered cordierite paragneiss, few very fine roots

Humpolec PP

Elevation: 528 m above sea level
Coordinates: 49°33´14.9´´N, 15°21´03.5´´E
Land use: crop agriculture, barley
Parent material: paragneiss
Ap: 0–28 cm, very dark grayish brown (10YR 3/2) moist and pale brown (10YR 6/3) dry, cloddy structure, loam texture, friable consistence, very few rock fragments, very few small fragments of bricks, common fine roots, clear, smooth boundary
Bw: 28–61 cm, yellowish brown (10YR 5/6) moist and brownish yellow (10YR 6/6) dry, prismatic structure, clay loam texture, friable consistence, common rock fragments, few fine roots, few charcoal, clear, smooth boundary
Cr: 61–118 cm, light grayish brown (10YR 6/2) moist and very pale brown (10YR 7/3), without structure,

loam texture, friable consistence, many rock fragments, approximately 40 % of this horizon are composed of medium-weathered paragneiss, few very fine roots

LP 35

Elevation: 426 m above sea level
Coordinates: 49°58′32.3′′N, 14°46′38.1′′E
Land use: nature preservation, beech forest
Parent material: Jevany type of granite
Oa: 0–10 cm, very dark brown (10YR 2/2) moist and dark brown (10YR 3/3) dry, very weakly developed blocky subangular structure, sandy loam texture, non-coherent consistence, many fine and very fine roots, clear, smooth boundary
Ah: 10–27 cm, black (10YR 2/1) moist and very dark gray, (10YR 3/1) dry, blocky subangular structure, sandy loam texture, soft consistence, very few rock fragments, common fine roots, gradual, smooth boundary
AhBw: 27–51cm, brown (10YR 4/3) moist and light brownish gray (10 YR 6/2) dry, blocky angular structure, sandy loam texture, friable consistence, common rock fragments, few fine roots, clear, smooth boundary
Bw: 51–71 cm, strong brown (7.5YR 4/6) moist and reddish yellow (7.5YR 6/6) dry, prismatic structure, sandy loam texture, friable consistence, many rock fragments, few fine roots, clear, smooth boundary
Cr: 71–111 cm, brownish yellow (10 YR 6/6) moist and very pale brown (10 YR 7/4) dry, without structure, sandy loam texture, very friable consistence, many rock fragments, approximately 60 % of this horizon are composed of weakly weathered granite of Jevany type, few fine roots

LP36

Elevation: 479 m above sea level
Coordinates: 49°57′59.3′′N, 14°46′48.5′′E
Land use: nature preservation, beech forest
Parent material: Říčany type of granite
Ah: 0–8 cm, black (10YR 2/1) moist and very dark brown (10YR 2/2) dry, very weakly developed blocky subangular structure, loam texture, very friable consistence, very few rock fragments, many fine roots, clear, smooth boundary
AhBw: 8–24 cm, brownish yellow (10YR 6/6) moist and yellow (10YR 7/6) dry, prismatic structure, loam texture, very friable consistence, few rock fragments, common fine roots, gradual, smooth boundary
Bw: 24–44 cm, strong brown (7.5YR 5/6) moist and reddish yellow (7.5YR 6/6) dry, prismatic structure, loam texture, very friable consistence, common rock fragments, few fine roots, clear, smooth boundary
Cr: 44–58 cm, yellowish brown (10YR 5/4) moist and very pale brown (10YR 8/3) dry, without structure, sandy loam texture, very firm consistence, many rock fragments, approximately 60 % of this horizon are composed of weakly weathered granite of Říčany type, few fine roots

The pits of Humpolec L, Humpolec PP, LP 35 and LP 36 were classified as a Cambisol soil type. The occurrence of Oa horizon was documented in the case of soil profiles LP 35 and LP 36. Oa horizon of soil profile LP 36 is 1 cm thick. The thicknesses of A horizons of individual soils are different. Transitional horizon ABw was detected only in the soils with granitic bedrock. Thickness of Bw horizon is higher in soil developed on paragneiss. Morphological analysis showed that the thickness of A horizons is connected with the character of land use. The thickness of Bw horizons and the content of rock fragments are probably influenced by the type of parent material.

MICROMORPHOLOGICAL CHARACTERICS OF SOIL PROFILES

The distribution of main micromorphological properties in the soil profiles take given in Table 1 (Humpolec L), Table 2 (Humpolec PP), Table 3 (LP 35) and Table 4 (LP 36). Micromorphological analysis allowed to identify a variety of soil developments on paragneiss and granite. Cambisols on paragneiss have pedofeatures such as droppings of enchytraeids only in the case of Ah and Ap horizons. Bw horizons of these soils show highly separated subangular blocky microstructure with brownish yellow, speckled, granostriated b-fabric and close porphyric c/f related distribution. The main components of groundmass are quartz and biotite. Apatite and ore minerals are present in small amounts. Cordierite was documented only in soil profile Humpolec L. The intensity of chemical weathering is higher in soils on cordierite paragneiss than in those on paragneiss. Cr horizons of these soils are also characterized by fragments of paragneiss. Cambisols on granite have pedofeatures such as droppings of enchytraeids and pellets of oribatid mites only in the case of Oa and Ah horizons. Bw horizons of these soils show moderately separated subangular blocky microstructure with strong brown speckled parallel striated b-fabric and open porphyric c/f related distribution. The main component of groundmass is quartz. Biotite, plagioclase and ore minerals are present in small amounts. The soil on granite of the Říčany type shows a better developed Bw horizon than that on granite of the Jevany type. Cr horizons also typically contain fragments of granite. The results showed some variability in soil processes of humification and formation of the cambic horizon on different parent materials. The moder form of humus was classified in the case of Oa horizons. Differences in A horizons are controlled by the land use and character of vegetation. The analysis of thin sections of Bw horizons showed the dominance of quartz and biotite in soils on paragneiss and the dominance of quartz in soils on granite. The soils on paragneiss show a higher intensity of chemical weathering than those on granite. Micromorphological data showed different levels of weathering of parent material in the Cr horizons.

Table 1 Micromorphological features of profile Humpolec L

Humpolec L	0–17 cm	17–49/69 cm	49/69–94 cm
Microstructure	moderately separated angular blocky with channels	highly separated subangular blocky with planes	bridged grain with few planes
Groundmass			
coarse material			
mineral	angular grains of quartz (fs-cs), biotite (fs-ms), small portion of muscovite (fs-ms), plagioclase (fs-ms), cordierite (fs) and ore minerals (fs)	angular grains of quartz (fs-cs), biotite (fs-ms), small portion of cordierite (fs), apatite and ore minerals (fs)	angular grains of quartz (cs), biotite (cs), small portion of cordierite (fs) and ore minerals (fs), fragments of cordierite paragneiss (cs)
organic	few remains of root sections		
micromass	very dark brown, dotted, undifferentiated b-fabric	brownish yellow, speckled, granostriated b-fabric	pale brown, speckled, granostriated b-fabric
c/f related distribution	close enaulic	close porphyric	gefuric
Pedofeatures	small portion droppings of enchytraeids		

fs – fine sand size, ms – medium sand size, cs – coarse sand size

Table 2 Micromorphological features of profile Humpolec PP.

Humpolec PP	0–28 cm	28–61 cm	61–118 cm
Microstructure	moderately separated angular blocky with packing	highly separated subangular blocky with planes	bridged grain with few planes
Groundmass			
coarse material			
mineral	angular grains of quartz (ms), biotite (fs), small portion of ore minerals (fs)	angular grains of quartz (ms-cs), biotite (ms-cs), small portion of apatite and ore minerals (fs)	angular grains of quartz (ms-cs), biotite (ms-cs), small portion of ore minerals (fs), fragments of paragneiss (cs)
organic	few remains of carbonized root section		
micromass	dark brown, dotted and speckled, undifferentiated b-fabric	brownish yellow, speckled, granostriated b-fabric	pale brown, speckled, granostriated b-fabric
c/f related distribution	close porphyric	close porphyric	gefuric
Pedofeatures	small portion droppings of enchytraeids		

fs – fine sand size, ms – medium sand size, cs – coarse sand size

PARTICLE SIZE DISTRIBUTION

The particle size distribution and texture classes of individual soil horizons are shown in Table 5. These data are lacking in the case of Oa horizon of soil profile LP 35 and Ah horizon of soil pit LP 36, where relatively high content of soil organic matter was detected. The particle size distribution of the examined profiles showed a general tendency with prevailing particle size category of sand.

PHYSICAL PROPERTIES

Physical properties of soils are presented in Table 6. Moisture is a highly variable property connected with land use and other parameters. The

Table 3 Micromorphological features of profile LP 35.

LP 35	0–10 cm	10–27 cm	27–51 cm	51–71 cm	71–111 cm
Microstructure	weakly separated granular with channels	moderately separated granular with channels	moderately separated angular blocky with channels and plains	moderately separated subangular blocky with planes	bridged grain with few planes
Groundmass					
coarse material					
mineral	angular grains of quartz (ms)	angular grains of quartz (ms), small portion of biotite (ms), plagioclase (ms) and ore minerals (ms)	angular grains of quartz (ms), small portion of biotite (ms), plagioclase (ms-cs) and ore minerals (ms)	angular grains of quartz (ms), small portion of biotite (fs-ms), plagioclase (fs-ms) and ore minerals (ms)	angular grains of quartz (ms-cs), small portion of biotite (fs-ms), plagioclase (fs-ms) and ore minerals (ms), fragments of Jevany granite type (cs)
organic	remains of root sections, leaf tissue fragments				
micromass	very dark brown, dotted, undifferentiated b-fabric	dark brown, dotted, undifferentiated b-fabric	brown, dotted and speckled, parallel striated b-fabric	strong brown, speckled, parallel striated b-fabric	light brown, speckled, parallel striated b-fabric
c/f related distribution	close enaulic	close enaulic	open porphyric	open porphyric	gefuric
Pedofeatures	pellets of oribatid mites and droppings of enchytraeids	small portion of oribateid mites			

fs – fine sand size, ms – medium sand size, cs – coarse sand size

Table 4 Micromorphological features of profile LP 36.

LP 36	0–8 cm	8–24 cm	24–44 cm	44–58 cm
Microstructure	moderately separated granular blocky with channels	moderately separated angular blocky with channels and planes	moderately separated subangular blocky with planes	bridged grain with planes
Groundmass				
coarse material				
mineral	angular grains of quartz (ms), small portion of biotite (ms), plagioclase (ms) and ore minerals (ms)	angular grains of quartz (ms-cs), small portion of biotite (ms), plagioclase (ms) and ore minerals (ms)	angular grains of quartz (ms-cs), small portion of biotite (ms), plagioclase (ms) and ore minerals (ms)	angular grains of quartz (ms-cs), small portion of biotite (ms), plagioclase (ms-cs) and ore minerals (ms), fragments of Říčany granite (cs)
organic	remains of root sections, leaf tissue fragments	few remains of root sections		
micromass	dark brown, dotted, undifferentiated b-fabric	brown, dotted and speckled, parallel striated b-fabric	strong brown, speckled, parallel striated b-fabric	light brown, speckled, parallel striated b-fabric
c/f related distribution	close enaulic	open porphyric	open porphyric	gefuric
Pedofeatures	pellets of oribatid mites and droppings of enchytraeids			

fs – fine sand size, ms – medium sand size, cs – coarse sand size

Table 5 Particle size distribution.

Locality	Depth cm	Clay %	Silt %	Sand %	Texture class
Humpolec L	0–17	9.6	42.1	48.3	loam
	17–49/69	10.1	36.3	53.6	sandy loam
	49/69–94	9.0	25.9	65.1	sandy loam
Humpolec PP	0–28	15.4	42.9	41.7	loam
	28–61	28.5	36.1	35.4	clay loam
	61–118	20.6	33.5	45.9	loam
LP 35	0–10	nd	nd	nd	nd
	10–27	8.3	18.6	73.1	sandy loam
	27–51	4.9	24.7	70.4	sandy loam
	51–71	5.7	21.5	72.8	sandy loam
	71–111	4.4	25.8	69.8	sandy loam
LP 36	0–8	nd	nd	nd	nd
	8–24	9.4	48.8	41.8	loam
	24–44	10.5	45.7	43.8	loam
	44–58	10.2	19.7	70.2	sandy loam

clay – <0.001mm, silt – 0.001–0.05 mm, sand – 0.05–2.00 mm, nd - not determined

highest value of moisture was measured in the upper part of soil profiles in the case of permanent grass cover and the lowest moisture in the forest. The evaluation of maximum capillary capacity and retention water capacity was done by Valla et al. (2002). The value of maximum capillary capacity is relatively good in all soils. Data of retention water capacity are heterogeneous for each horizon of the individual soil profiles. Such distribution can be influenced by the size and type of rock fragments. The value of bulk density increases in the direction to the parent material with the exception of arable soil, where practically the same value was obtained in the whole profile. The highest bulk density was measured in Ap horizon of arable soil and the lowest in Oa horizon of the forest. Differences in bulk density in the upper part of forest soils were probably caused by different stages of litter decomposition. Particle density characterised the solid phase of soil without pores. This value is used for porosity calculation. Differences in particle density of the studied Cambisols are predominantly connected with the type of parent material and, in the case of A horizons, with the content of soil organic matter. Porosity is calculated from the bulk and particle density. The distribution of porosity in soil profiles has an opposite tendency to bulk density in all cases. Bulk density, porosity and particle size distribution were used for the evaluation of compaction soils by Lhotský (2000). These properties were analysed as critical for arable Cambisol developed on paragneiss. The different physical properties of Cambisols developed on paragneiss are influenced by the type of land use. Cambisol developed on granite in forest conditions has better characteristics. Some dissimilarity in this condition in the upper part of the soil profiles are controlled by the quality of soil organic matter.

SOIL CHEMICAL PROPERTIES

Data on soil chemical properties are summarized in Table 7. The values of pH are very acid in soils at Humpolec and hyperacid in the Voděradské bučiny National Nature Reserve. Cation exchange capacity is the highest in the O and A horizons of all soils. The value of cation exchange capacity is relatively higher in soils developed on paragneiss. The content of exchangeable potassium, calcium and magnesium commonly depends on the type of parent material, and is higher in soil profiles at Humpolec. The values of base saturation do not exceed 21 % in soil profiles in the Voděradské bučiny National Nature Reserve. These values range from 44 to 74 % in soils on paragneiss whereas a higher base saturation was found on agricultural crop. A more detailed soil nomenclature of Cambisols was elaborated based on the chemical properties, especially on the values of base saturation. The soil profiles from Humpolec are classified as Haplic Cambisols. The soils studied in the Voděradské bučiny National Nature Reserve are covered with Dystric Cambisols.

Table 6 Physical properties.

Locality	Depth cm	M %	MCC %	RWC %	BD %	PD %	P %
Humpolec L	0–17	43.90	50.94	45.25	1.08	2.48	56.45
	17–49/69	44.70	40.37	34.06	1.36	2.62	48.09
	49/69–94	18.85	26.59	17.79	1.58	2.68	41.05
Humpolec PP	0–28	28.66	38.84	35.04	1.59	2.55	37.65
	28–61	33.29	37.64	33.55	1.61	2.68	39.93
	61-118	31.88	36.99	32.84	1.63	2.67	38.95
LP 35	0–10	15.17	43.01	36.77	0.22	1.58	86.07
	10–7	40.29	55.62	48.93	0.48	1.75	72.57
	27–51	13.94	31.60	23.29	1.44	2.55	43.53
	51–71	12.73	34.44	27.80	1.36	2.59	47.49
	71–111	13.20	22.08	14.84	1.35	2.59	47.88
LP 36	0–8	21.69	30.10	26.89	0.85	2.18	61.00
	8–24	22.96	41.68	36.77	1.26	2.56	50.78
	24–44	15.65	31.20	22.44	1.32	2.59	49.03
	44–58	nd	nd	nd	nd	nd	nd

M – moisture, MCC – maximum capillary capacity, RWC – retention water capacity, BD – bulk density, PD – particle density, P – porosity, nd – not determined

Table 7 Chemical properties.

Locality	Depth cm	pH_{H2O}	pH_{KCl}	CEC cmol/kg	K^+ cmol/kg	Ca^{2+} cmol/kg	Mg^{2+} cmol/kg	BS %
Humpolec L	0–17	4.49	3.93	18.81	0.66	6.85	0.84	44
	17–49/69	4.72	4.03	11.12	0.13	4.75	0.46	48
	49/69–94	4.72	3.96	6.99	0.10	3.19	0.38	53
Humpolec PP	0–28	5.09	4.53	17.95	0.51	9.51	1.18	62
	28–61	4.92	3.97	17.40	0.29	11.21	1.79	76
	61–118	4.43	3.37	21.43	0.37	12.65	2.77	74
LP 35	0–10	3.42	2.68	98.50	1.05	5.19	1.27	8
	10–27	3.00	2.20	86.70	0.22	0.93	0.66	2
	27–51	3.70	2.95	8.60	0.06	0.08	0.04	2
	51–71	4.05	3.70	11.50	0.06	0,06	0.02	1
	71–111	3.95	3.45	5.90	0.06	0.12	0.03	2
LP 36	0–8	3.94	3.22	45.52	0.53	3.18	0.54	9
	8–24	4.33	3.93	11.24	0.02	0.04	0.05	1
	24–44	4.31	4.12	8.40	0.01	0.04	0.05	1
	44–58	4.83	3.80	4.06	0.05	0.49	0.31	21

CEC – cation exchange capacity, K^+ – exchangeable potassium, Ca^{2+} – exchangeable calcium, Mg^{2+} – exchangeable magnesium, BS – base saturation

Table 8 Soil organic matter.

Locality	Depth cm	C_{ox} %	N_t %	C/N	C_{hw} % C_{ox}	C_{hw} mg/kg
Humpolec L	0–17	2.77	0.25	11.08	3.75	1040
	17–49/69	1.36	0.12	11.33	1.05	142
	49/69–94	0.52	0.05	10.40	1.80	93
Humpolec PP	0–28	1.36	0.17	8.00	2.07	281
	28–61	0.55	0.05	11.00	2.11	116
	61–118	0.36	0.05	7.20	2.79	100
LP 35	0–10	36.61	1.55	23.62	4.92	17841
	10–27	19.03	0.83	22.93	4.92	12165
	27–51	0.89	0.05	17.80	3.83	525
	51–71	0.89	0.04	22.25	4.34	581
	71–111	0.36	0.02	18.00	5.86	305
LP 36	0–8	10.60	0.57	18.60	5.32	7154
	8–24	1.14	0.21	5.43	2.70	432
	24–44	0.73	0.04	18.25	1.08	150
	44–58	0.16	0.01	16.00	1.40	132

C_{ox} – organic carbon, C_{hw} – hot–water extractable carbon, N_t – total nitrogen

SOIL ORGANIC MATTER

The distribution of organic carbon, hot-water carbon, nitrogen and C/N ratio within the profiles is presented in Table 8. Values of organic carbon are the highest in upper parts of the profiles but the content of soil organic matter is different. The highest values of soil organic matter were identified in forest soils in soil profiles LP 35 and LP 36, and the lowest values in the experimental field at Humpolec. The reserves of soil organic matter according to land use are (in descending order): nature protection (forest) – permanent grass cover – crop agriculture. The reserves of soil organic matter can be connected with the sources of soil biomass. The content of hot-water extractable carbon is an important indicator of the state of the soil organic matter, which can compensate for the hitherto used parameters, such as humic acids, fulvic acids etc. The distribution the value of hot–water extractable carbon in % within the profiles is different. This parameter is uniform at Humpolec PP. The values of this quality decrease to the C horizons at Humpolec L and LP 36. An opposite tendency was recorded in the area of LP 35. The C/N ratio was evaluated by Orlov (1985). The C/N value showed that the stock of N in the A and O horizons is low at locality LP 35 and LP 36, average at Humpolec L and high in area of Humpolec PP. The quality parameter C/N also indicated a lower degree of decomposition of soil biomass in Oa and Ah horizons of forest soils (LP 35, LP 36). The formula $R = BD \times T \times C$ where R denotes the reserves of C_{ox} (t/ha), BD is bulk density (g/cm^3), T is thickness of the layer (cm) and C is C_{ox} content for respective interval (%), was used for the calculation of the reserves of soil organic matter at individual localities. Reserves of organic carbon (t/ha) in the upper 25 cm are as follows at the studied localities: Humpolec L – 65.60; Humpolec PP – 54.06; LP 35 – 217.56; LP 36 – 92.09. The results obtained in this study indicate that the reserves of C_{ox} correspond to the source of aerial and below-ground biomass and also to the type of land use. Reserves of soil organic matter are the highest in forests and the lowest in agricultural areas.

MINERALOGY

Mineral composition of the fraction <0.001 mm is given in Table 9. The X-ray diffractograms of the clay fraction from Bw horizons are given in Figure 1 (Humpolec PP – paragneiss) and Figure 2 (LP 36 – granite). Haplic Cambisol on paragneiss in agricultural landscape conditions (Humpolec PP) has a high content of illite and kaolinite. The contents of chlorite, smectite and interlayered illite–vermiculite are smaller. The smaller content of feldspars is typical for the soils developed on paragneiss. A very similar mineral composition, except for the elevated chlorite content and the absence of smectite in all profiles, was found in Haplic Cambisol on cordierite paragneiss in the case of permanent grass cover (Humpolec L). This fact can be explained by the presence of cordierite

Table 9 Mineral composition of the fraction <0.001 mm.

Locality	Depth	A	Ch	I	I–S	I–V	K	F	L	P	Q	S
	cm	%	%	%	%	%	%	%	%	%	%	%
Humpolec L	0–17	0	15	26	0	14	17	4	0	4	20	0
	17–49/69	0	21	26	0	0	17	3	0	3	30	0
	49/69–94	0	17	18	0	7	10	4	0	2	42	0
Humpolec PP	0–28	0	5	32	0	0	25	5	0	4	29	0
	28–61	0	2	25	0	2	21	5	0	4	40	1
	61–118	0	0	16	0	6	24	9	0	4	32	9
LP 35	0–10	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	10–27	0	17	10	0	0	22	8	0	13	30	0
	27–51	1	3	4	11	0	13	6	1	5	29	28
	51–71	0	8	2	8	0	8	17	0	13	45	0
	71–111	0	8	2	0	0	10	15	1	15	50	0
LP 36	0–8	0	5	2	0	0	3	7	0	6	79	0
	8–24	0	22	2	0	0	6	9	0	7	55	0
	24–44	0	36	7	0	0	9	8	0	6	34	0
	44–58	0	11	10	2	0	6	14	2	13	41	0

A – amphibole, Ch – chlorite, I – illite, I–S – illite-smectite, I–V- illite-vermiculite, K – kaolinite, F– K–feldspar, L – lepidocrocite, P – plagioclase, Q – quartz, S – smectite, nd – not determined

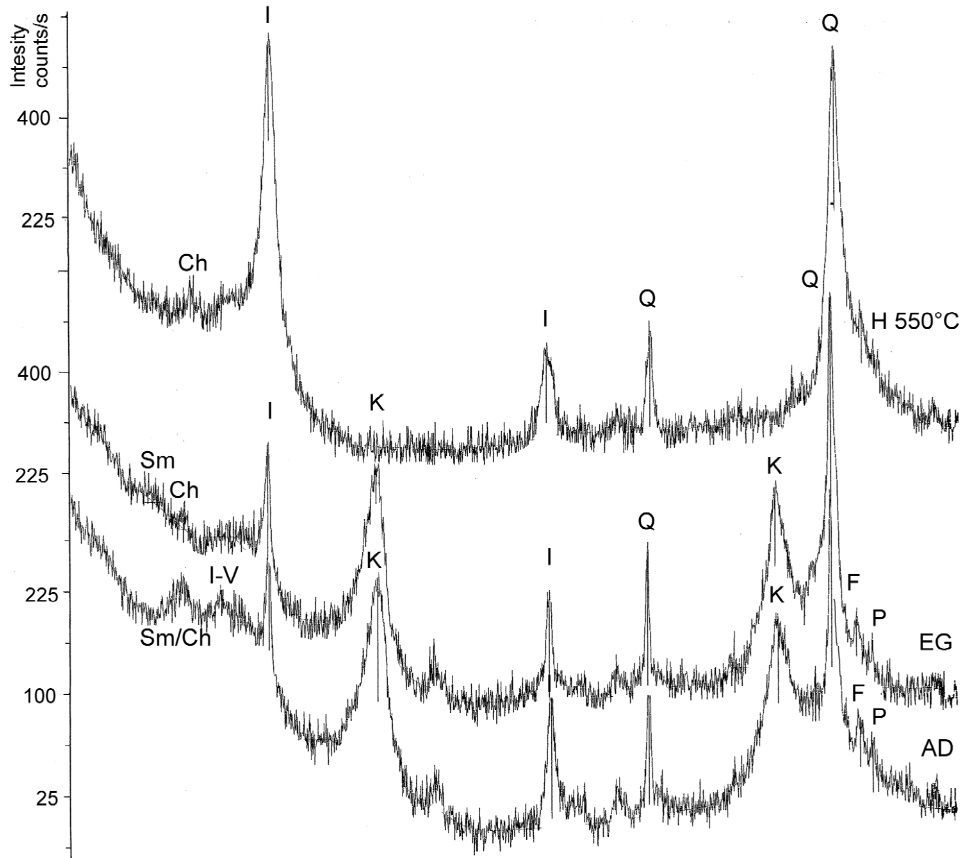

Fig. 1 X–ray diffractogram of clay fraction from the Bw horizon developed on paragneiss (Humpolec PP). AD – air-dried, EG – ethylene glycol solvated, H – heating, Ch - chlorite, I – illite, I–V –illite–vermiculite, K – kaolinite, F – K-feldspar, P – plagioclase, Q – quartz, S – smectite

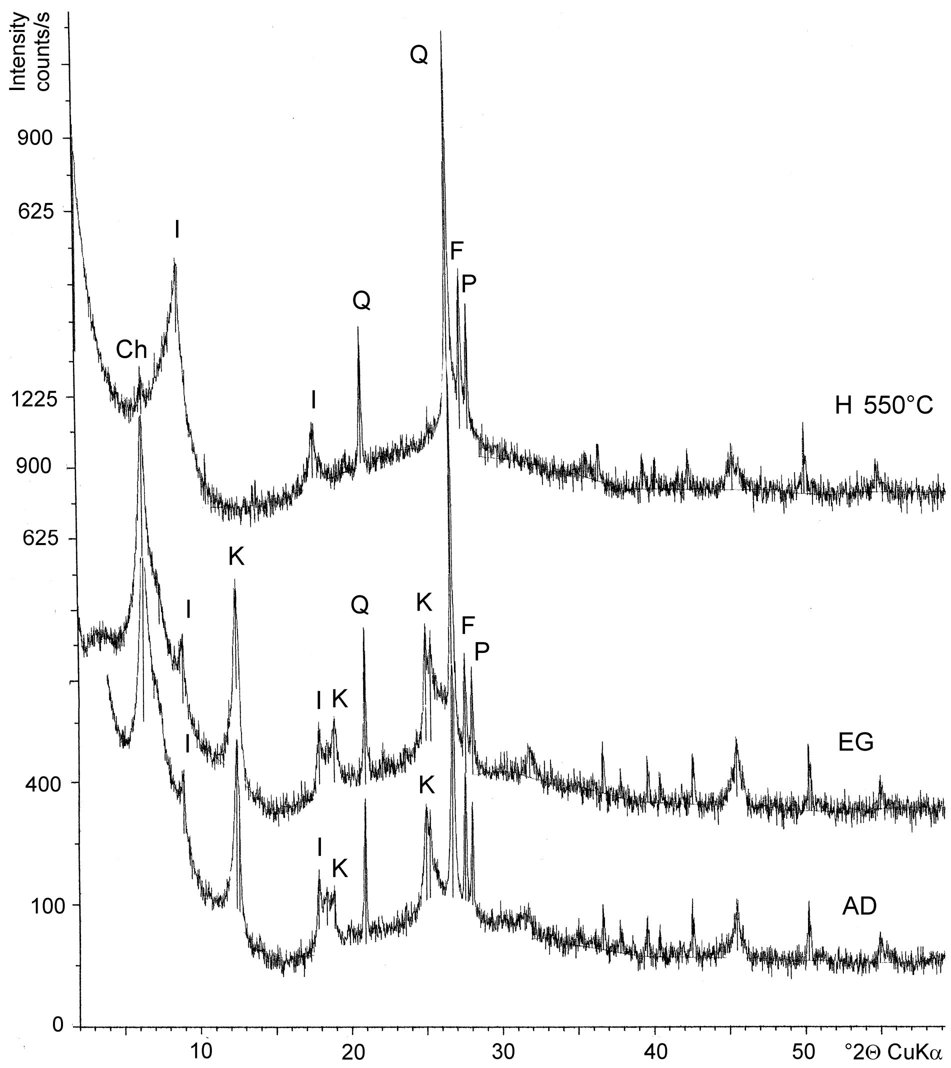

Fig. 2 X–ray diffractogram of clay fraction from the Bw horizon developed on granite (LP 36). AD – air-dried, EG – ethylene glycol solvated, H – heating, Ch – chlorite, I – illite, K – kaolinite, F – K-feldspar, P – plagioclase, Q – quartz

paragneiss, where cordierite weathers into pinite (mixture of sericite and chlorite). The localities of Humpolec L and Humpolec PP have very similar contents of quartz, feldspars, kaolinite and illite. These mineral compositions correspond to the development of soils on paragneiss. Dystric Cambisol on the Jevany type of granite (LP 35) is a typical example of soil developed on granite with the presence of quartz and higher content of feldspar together with their weathering products such as kaolinite, illite and chlorite. Transitional types of transformation, such as smectite and interlayered illite–smectite, are present in this soil profile. AhBw and C horizons contain a small portion of lepidocrocite. Dystric Cambisol on the Říčany type of granite (LP 36) contains chloritized biotite and partly argillized feldspar which is reflected by the high content of chlorite in the soil profile. The alteration of biotite into chlorite was described by Eggleton and Banfield (1985). Presence of other clay minerals such as kaolinite, illite and interlayered illite-smectite is smaller. C horizon contains a small portion of lepidocrocite.

In contrast to soils developed on granite, soils on paragneiss have high contents of illite a kaolinite and lower contents of K-feldspar and plagioclase. This mineral composition showed that the soils developed on paragneiss show a higher degree of weathering of the parent material and also a higher intensity of the development of Bw horizon.

CONCLUSION

The main pedogenic process in soils developed on paragneiss and granite under very similar climatic conditions in southeastern Bohemia is the formation of the cambic horizon.

Soils developed on paragneiss in the Humpolec area were classified as Haplic Cambisols. Soils developed on granite in the Voděradské bučiny National Nature Reserve were classified as Dystric Cambisols.

The particle size distributions, physical, chemical and mineral properties of Cambisols were influenced to a variable degree by the type of parent material.

Physical properties of soils are controlled by the type of parent material and by the type of land use, especially in the upper part of soil profiles (Oa and A horizons). The best physical properties are displayed by soils with permanent grass cover.

Haplic Cambisols developed on paragneiss have more favourable chemical properties (pH, cation exchange capacity, base saturation) than Dystric Cambisols on granite.

The content and quality of soil organic matter are connected with the type of vegetation and land use. Soils in the forest show the highest contents and reserves of organic matter, which is connected with the presence of relatively high amount of litter. The quality parameter C/N indicated a lower degree of decomposition of soil biomass in Oa and Ah horizons of forest soils (LP 35, LP 36), and very similar in the case of permanent grass cover and arable soil.

Specific pedogenic processes of litter formation operate in the forest. Agroturbation is typical for arable soil. Soils developed on paragneiss are characterized by a stronger weathering of parent material than the soils on granites. The thickness and intensity of formation of cambic horizons is influenced by the type of parent material. Soils developed on paragneiss have a better developed Bw horizon than the soils on granites.

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