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ORIGINAL PAPER

MINERAL COMPOSITION OF RENDZIC LEPTOSOLS IN PROTECTED AREAS OF THE CZECH REPUBLIC

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ABSTRACT

This study overviews Rendzic Leptosols developed on different limestones of pre-Mesozoic age in protected areas of the Czech Republic, and characterizes their pedogenesis and mineral composition. The parent material originating from unmetamorphosed, low- and high-grade metamorphic rocks (sites Cikánka, Třesín and Vyšenské kopce, respectively) was evaluated on the basis thin section of petrography and X-ray diffractometry of powder samples. Representative soil sequences were characterized by macromorphological analysis, particle size distribution, chemical properties, parameters of soil organic matter and mineral composition of clay fraction. Soil formation is limited to the thickness of Ahk horizons. The process of humification is controlled by the source of biomass and biological activity. Třesín and Vyšenské kopce have more favourable parameters of humification than Cikánka. Mineral composition of Rendzic Leptosols is significantly affected by the petrography of parent material and local conditions of bedrock. Unmetamorphosed limestones from Cikánka are the most characteristic parent material for the development of Rendzic Leptosols.

INTRODUCTION

Rendzic Leptosols are distributed over calcareous bedrock in the Czech Republic. These soils have a more developed structure and a higher intensity of biological activity than other Leptosols. The development of these soils is affected by humus formation and weathering of parent material. Limestone is the most widespread parent material of Rendzic Leptosols in the territory of the Czech Republic.

Many aspects of pedogenesis are still poorly known for Rendzic Leptosols. Most studies on the mineralogy of these soils come from various limestone districts of Europe, e.g., England, Wales, France and Spain (Khan, 1960), Slovakia (Šály and Mihálik, 1970), Germany (Küfmann, 2003) and Poland (Zagórski, 2003, 2010). In the territory of the Czech Republic the development of these soils was described from the viewpoint of ecology and soil microstructure (Kubíková and Rusek, 1976).

The main objective of this study is to present an overview of Rendzic Leptosols developed on different types of limestones from various parts of the Czech Republic and characterize the basic properties and mineral composition of these soils.

GEOLOGICAL SETTINGS AND STRATIGRAPHY

BARRANDIAN AREA

The site of Cikánka is located in the closest southeastern neighbourhood of the former quarry buildings with a forge Na Cikánce 614/2, built in 1950s, today close behind the eastern wall of the Špička Quarry. The basement rocks, fractured and weathered in regolith, are Devonian limestones of the folded and faulted upper allochthonous unit of the Prague Synform which is the uppermost preserved unit of the Bohemicum (Melichar and Hladil, 1999; Melichar, 2004; Cháb et al., 2010). Alternative names for this area are also used in the literature, e.g. eastern part of the central Barrandian or Prague Basin (e.g., Chlupáč et al., 1998; Chlupáč et al., 2002; Ferrová et al., 2012). The calciturbidite-hemipelagite successions of strata which reach the surface at this site encompass the transition from the Dvorce-Prokop to the Řeporyje facies of the Praha Formation (Chlupáč et al., 1998; Koptíková et al., 2010).

The stratigraphic age of these Lower Devonian limestones is Lower Emsian in the presently valid concept but the exact stratigraphic level lies close below the Graptolite Dysoxic Event beds which can be selected as a future Pragian–Emsian boundary (Hladil et al., 2011). The present estimation of the sedimentary and early diagenetic absolute age can be about 403 ± 3 Ma (cf. Cohen et al., 2013; Gradstein et al., 2012). In the time of eo-Variscan and Variscan orogenies, these rocks were never regionally heated to over ca. 100 °C, with the maximum burial episodes between the Frasnian and Lower Visean, in a time span of ca. 375–340 Ma (Filip and Suchý, 2004).

MORAVO-SILESIAN ZONE

The site of Třesín lies at the eastern base of Třesín Hill, precisely behind the Mladečská myslivna (Mladeč Gamekeeper's Lodge). The limestones at this site belong to the fragmentary Konice-Mladeč Belt in central Moravia which contains discrete allochthonous fragments and megablocks of Devonian sedimentary rocks which were slightly metamorphosed and detached together with partly preserved Neoproterozoic basement rocks and the overlying Mississippian facies. Some parts have also the form of klippen - remnants of nappes (Přichystal, 1996). These megablocks are aligned along Variscan thrust faults and lie between different folded and faulted massifs of Culmian (Mississippian flysch) turbidites (Hladil et al., 1999; Bábek et al., 2006). The blocks were often characterized as fragments of continental slope sequences, i.e., as a transitional facies development intermittently spanning the space between the deepest and shallowest depositional environments. The Mladeč segment possibly contains the shallowest Devonian facies compared, therefore, with the northern Moravian Karst platform-reef facies (Bábek et al., 2006). At Třesín Hill, the thickness of these light grey rigid limestones is elevated of tectonic reasons (compression, numerous small thrust faults – e.g., Pošmourný and Coubal, 1993). In meso- and microscale, they display many faults, microfaults, tectonic breccias and veins. A very significant aspect of the sampled site is that the coarse crystalline calcite material from veins strongly predominates over the host rocks.

Estimates of stratigraphic age of the Middle–Upper Devonian limestones (host rocks of tectonic breccias and veins) are, due to recrystallization of fossils, considerably approximate, pointing to the time span from middle/late Givetian to early/middle Frasnian (cf. Hladil, 1993). This corresponds to ca. 385–375 Ma (Cohen et al., 2013). The material in calcite vein/breccia is, however, much younger than the host rock. The age of this material is, most likely, late and end-Variscan (Pennsylvanian; cf. Grabowski et al., 2008), and parts of the fills are possibly Cenozoic. The latest observed faults at Třesín even cut loess deposits (O. Bábek, personal communication, 2013). The maximum temperatures for the host rocks and end-Variscan vein/breccia calcites are estimated at about 200–250 and 100–150 °C, respectively (Franců et al., 2002). The crystallization of late Cenozoic calcites in adjacent parts of the Drahany Upland usually corresponds to temperatures not exceeding 50 °C (Kučerová-Charvátová et al., 2005).

MOLDANUBICUM, VARIEGATED GROUP

The site of Vyšenské kopce lies on NW slope of Městský Hill, 1.6 km NNW of the Český Krumlov town centre. Crystalline limestones (marbles) belong to the Český Krumlov Variegated Unit which contains various types of paragneisses with calcium-rich and graphitic silicate metamorphic rocks as well as metavolcanics (amphibolites). At the studied site, calcite marbles strongly predominate over calcite–dolomite marbles, and this significantly contributes to the observed magnesium deficiency in the soil samples. The calcite marbles of 80 % purity alternate with stripes of marbles of lower, e.g. 50 %, purity. Quartzite and amphibolite bands and smears were also observed in close vicinity of the site (S. Houzar, personal communication, 2013). The marble stripes of lower purity (this case) are typical by significantly elevated content of quartz and plagioclases. Other typical accessory minerals of fresh marble samples are light grey to brownish phlogopite, graphite, pyrrhotite and greenish diopside, and occasionally also edinitic amphibole to tremolite (Novák et al., 2002). Here, the rarely represented whitish scapolite containing marialite component, locally also dravite, may be indicative of evaporite components in metasedimentary protolith and/or hydrothermal activity (Kadounová, 1987; Kříbek, 1988; Kříbek et al., 1997; Kříž, 2009). In addition, greenish-brownish forsterite occurs together with accessory dolomite, but is mostly serpentinized (Kříbek 1988).

The original ages of metasedimentary protolith are still under investigation, assumed to be Late Neoproterozoic to Early Palaeozoic (late Cryogenian to Eifelian; ~ 650–390 Ma); the metamorphic processes culminated, according to the deformation record, before the uplift and final deformation of these rock complexes (Rajlich et al., 1986; Maierová et al., 2012). The latter took place in Late Visean (at ca. 330–335 Ma), very close before the phase-related partial melting which led to the emplacement of migmatite components, aplites and pegmatites (Melleton et al., 2012). Related to this Visean origin of marbles, the graphite thermometer and mineral association (~ sillimanite subfacies of amphibolite facies) are indicative of maximum temperatures of about 600 °C and pressures of 0.6 GPa at medium values of XCO_2 > 0.2 (Kříbek, 1988; S. Houzar, personal communication, 2013).

MATERIAL

The study was performed in the protected areas. The positions of selected sites are presented in Figure 1 (cf. GPS coordinates in Results). Basic information about climate was described by Quitt (1971) and geomorphological regionalization by Bína and Demek (2012).

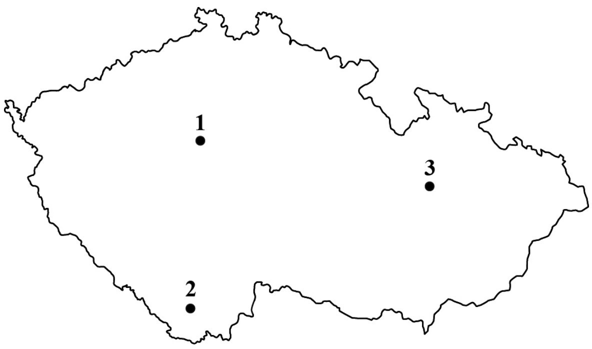

Fig. 1 Location of soil profiles 1 – Cikánka, 2 – Vyšenské kopce, 3 – Třesín.

The study area of the Cikánka National Nature Monument lies in the southwestern part of Prague and belongs to the geomorphological unit of the Prague Plateau. The most widespread are thermophilic rocky steppe communities. At the southeastern edge of this protected area, pine placed in thermophilic oak woods was planted on a hill above the quarry in the past. Climatic conditions of this locality are characterized by average annual precipitation of 600–700 mm, average annual temperature of 8–9 °C, with long, warm and dry summer, a very short transition period with warm to moderately warm spring and autumn. Winter is short, moderately warm, dry to very dry, with very short duration of snow cover.

The next studied site is located 232 km to the southeast of Prague in the Třesín National Nature Monument in the Zábřežská Highland. Whole area is characterized by typical thermophilic limestone vegetation and by forest consisting of warm oak-hornbeam groves and oak woods with beech. Climatic conditions are the same as for the Cikánka National Nature Monument.

The last area is located 178 km to the south of Prague in the Vyšenské kopce National Nature Reserve and belongs to the Šumava Piedmont. Open-stand growths with predominant Scots pine are typical for the limestone basement on the southern slopes. More acidic basements host acidophilous beech communities and fragments of acidophilous oak woods. Along the two streams, remnants of alder stands occur together with a mosaic of wetland meadows. A part of the territory is covered with woody vegetation consisting of tall shrubs and low trees with predominant hazel. The character of vegetation has been influenced by human activities for centuries. The open grassland–herbal communities were formed as a result of grazing. Climatic conditions of this locality are characterized by average annual precipitation of 500–600 mm, average annual temperature of 6–7 °C, with normal to short summers, mild to moderately cold, dry to moderately dry, with a normal to long transition period with mild spring and mild autumn. Winter is normally long, moderately cold, dry to moderately dry, with normal to short snow cover.

METHODS

Typical sequences were chosen on the basis of soil survey. Soil profiles were situated in the middle part of the slope. GPS coordinates of the soil profiles (WGS84 system) were measured by GARMIN eTrex Summit. Soil profiles were excavated down to the parent material. Basic morphological description and horizon designation was done according to Jahn et al. (2006). Individual soil profiles were classified according the World Reference Base for Soil Resources (IUSS Working Group WRB, 2007). Colours were identified using the Munsell Soil Color Charts (2000). The field description contains information about preliminary presence of calcium carbonate in the soil matrix of individual profiles. This test was done by adding a few drops of 10 % HCl to the individual pits. All samples, except those from O horizons, were collected from soil pits. Analytical procedures for soil characterization followed 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 with a SenTix21 electrode using a soil:solution ratio of 1:2.5. Determination of carbonate content was done by volumetric method using 10 % HCl. Exchangeable cations were determined using the method of Mehlich. Organic carbon was determined by wet combustion with a mixture of potassium dichromate and sulphuric acid, hot-water extractable carbon by Ghani (2003) with a modification by Krejčová (Žigová et al., 2007) and nitrogen using the Kjedahl method. Thin sections of parent material were examined with the OLYMPUS BX51 polarizing microscope with the DP70 digital camera. Powder samples of parent material and soil clay fraction were prepared for X-ray diffractometry. Prior to the X-ray analysis of soil samples, organic matter was removed using 30 % H_2O_2, and carbonates were removed by 0.1 N chloroacetic acid. The samples were then washed 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 ethyleneglycole at 80 °C and heated at 550 °C for 4 hours. X-ray diffraction (XRD) spectra were obtained on the PW3020 Philips X'Pert diffractometer with CuKα radiation (Třesín and Vyšenské kopce) and CoKα radiation (Cikánka) under a voltage of 40 kV and intensity of 55 mA. XRD patterns were recorded at a goniometric shift 1 ° min^{-1} 2Θ. Semiquantitave values were calculated based on the height of individual mineral basal peaks using correction coefficients (K. Melka, personal communication, 2013).

RESULTS AND DISCUSSION

SOIL MORPHOLOGY

Examination and description of soil profiles in the field was done to provide reliable information on soil morphology and classification. Main soil properties such as colour, structure, texture, abundance of rock fragments, preliminary content of carbonates, roots and biological activity were studied in three soil pits. The thickness of O horizons was 2 cm. This layer was detected in the Cikánka National Nature Monument and Třesín National Nature Monument. This layer is black in colour (10YR 2/1) when moist and very dark gray (10YR 3/1) when dry.

Cikánka (Fig. 2a)
Elevation: 252 m above sea level
Coordinates: 50°00´01.6´´N, 14°19´46.8´´E
Land use: forest

a)
b)
c)


Table 2 Soil profiles: a) Cikánka, b) Třesín, c) Vyšenské kopce (Photos A. Žigová).

Parent material: Lower Devonian limestones
Ahk$_1$: 0–9 cm, very dark brown (10YR 2/2) when moist and dark greyish brown (10YR 4/2) when dry, blocky subangular structure, silt loam texture, very friable consistence, few rock fragments, strongly calcareous, many fine roots, few earthworm excrement, clear, smooth boundary
Ahk$_2$: 9–22 cm, very dark greyish brown (10YR 3/2) when moist and brown (10YR 4/3) when dry, blocky subangular structure, silt loam texture, very friable consistence, common rock fragments, extremely calcareous, common fine roots, clear, smooth boundary
Ahk$_2$Crk: 22–45 cm, dark brown (10YR 3/3) moist and brown (10YR 5/3) dry, without structure, silty clay loam texture, very friable consistence, many rock fragments, extremely calcareous, few very fine roots, clear, smooth boundary
Crk: 45–105 cm, light grey (10YR 7/2) when moist and very pale brown (10YR 8/2) when dry, silt loam texture, very friable consistence, approximately 70 % of this horizon are composed of medium-weathered parent material, extremely calcareous

Třesín (Fig. 2b)
Elevation: 238 m above sea level
Coordinates: 49°42´32.9´´N, 17°01´05.3´´E
Land use: forest
Parent material: Middle–Upper Devonian limestones
Ahk$_1$: 0–6 cm, very dark brown (10YR 2/2) when moist and dark greyish brown (10YR 4/2) when dry, granular structure, silt loam texture, very friable consistence, few rock fragments, slightly calcareous, many fine roots, common earthworm excrements, clear, smooth boundary
Ahk$_2$: 6–19 cm, dark yellowish brown (10YR 3/4) when moist and yellowish brown (10YR 5/4) when dry, granular structure, silty clay loam texture, very friable consistence, few rock fragments, slightly calcareous, common fine roots, clear, smooth boundary
Ahk$_2$Crk: 19–56 cm, dark yellowish brown (10YR 4/4) when moist and light yellowish brown (10YR 6/4) when dry, without structure, silt loam texture, very friable consistence, many rock fragments, slightly calcareous, few very fine roots, clear, smooth boundary
Crk: 56–96 cm, yellowish brown (10YR 5/6) when moist and brownish yellow (10YR 6/6) when dry, without structure, silt loam texture, very friable consistence, approximately 70 % of this horizon are composed of medium-weathered parent material, moderately calcareous

Vyšenské kopce (Fig. 2c)
Elevation: 590 m above sea level
Coordinates: 48°49´25.1´´N, 14°18´15.6´´E
Land use: permanent grass cover
Parent material: crystalline limestones with various types of paragneisses with calcium-rich and graphitic silicate metamorphic rocks as well as metavolcanics (amphibolites)
Ahk$_1$: 0–10 cm, very dark greyish brown (10YR 3/2) when moist and dark brown (10YR 3/3) when dry, blocky subangular structure, loam texture, very friable consistence, few rock fragments, moderately calcareous, many fine roots, common earthworm excrements, common conchs of molluscs, clear, smooth boundary
Ahk$_2$: 10–23 cm, dark greyish brown (10YR 4/2) when moist and brown (10YR 5/3) when dry, blocky angular structure, loam texture, friable consistence, common rock fragments, moderately calcareous, few fine roots, clear, smooth boundary
Ahk$_2$Crk: 23–46 cm, dark brown (10YR 3/3) when moist and brown (10YR 4/3) when dry, without structure, loam texture, friable consistence, many rock fragments, strongly calcareous, clear, smooth boundary
Crk: 46–80 cm, brownish yellow (10YR 6/6) when moist and yellow (10YR 7/8) when dry, without structure, sandy loam texture, firm consistence, approximately 80 % of this horizon are composed of medium-weathered parent material, extremely calcareous

Table 1 Particle size distribution.

Locality	Depth cm	Clay %	Silt %	Sand %	Texture class
Cikánka	0–9	19.2	64.6	16.2	silt loam
	9–22	24.2	62.1	13.7	silt loam
	22–45	28.3	58.5	13.2	silty clay loam
	45–105	17.3	60.6	22.1	silt loam
Třesín	0–6	26.5	59.8	13.7	silt loam
	6–19	29.6	57.1	13.3	silty clay loam
	19–56	26.8	57.9	15.3	silt loam
	56–96	21.7	61.3	17.0	silt loam
Vyšenské kopce	0–10	11.2	41.1	47.7	loam
	10–23	11.9	41.4	46.7	loam
	23–46	10.5	40.2	49.3	loam
	46–80	7.0	18.7	74.3	sandy loam

Table 2 Chemical properties.

Locality	Depth cm	$CaCO_3$ %	pH_{H2O}	pH_{KCl}	BS %	K^+ $cmol^{(p+)} \cdot kg^{-1}$	Ca^{2+} $cmol^{(p+)} \cdot kg^{-1}$	Mg^{2+} $cmol^{(p+)} \cdot kg^{-1}$
Cikánka	0–9	24.00	7.62	7.58	100	1.10	37.06	1.83
	9–22	30.00	7.68	7.50	100	0.52	27.39	0.99
	22–45	28.00	7.76	7.59	100	0.44	26.13	0.99
	45–105	52.00	7.97	7.80	100	0.20	16.91	0.75
Třesín	0–6	0.15	5.71	4.85	83	2.98	25.93	3.01
	6–19	0.15	4.71	3.39	55	1.53	11.35	1.56
	19–56	0.10	5.98	5.14	100	1.12	24.51	1.14
	56–96	5.00	7.51	7.13	100	0.25	27.60	0.27
Vyšenské kopce	0–10	3.80	7.51	7.05	100	0.23	40.68	0.76
	10–23	5.00	7.56	7.07	100	0.13	30.44	0.38
	23–46	13.00	7.70	7.17	100	0.10	30.72	0.18
	46–80	34.00	8.11	7.56	100	0.04	18.74	0.10

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

Configuration of soil profiles indicated that humification is the principal pedogenic process of these soils. The studied soils are relatively shallow, developed on calcareous parent material. The description of soil organisms showed that the biological activity is lower at the Cikánka National Nature Monument than at other localities. The thicknesses of Ahk horizons of the studied soils are very similar. The occurrence of Ahk_2Crk horizon was documented at all sites but this horizon is better developed at the Třesín National Nature Monument than at other sites. Different contents of carbonates in soil matrix of individual profiles are probably influenced by the types of limestones. Morphological analysis allowed to classify all soils as Rendzic Leptosols although they show some differences in soil development.

PARTICLE SIZE DISTRIBUTION

The results of particle-size analysis (Table 1) show some differences and similarities in the distribution of individual particle sizes. Soil profiles have different contents of clay fraction. Silt fraction dominates at the Cikánka National Nature Monument and Třesín National Nature Monument. The particle size distribution of Rendzic Leptosol is probably a function of the type of limestones. Results of classification by texture classes also reflect this possibility.

CHEMICAL PROPERTIES

Data on soil chemical properties are summarized in Table 2. The results of the determination of carbonates during field works and laboratory works are very similar. The lowest content of carbonates was documented at Třesín and the highest one at Cikánka. These localities have the same climatic conditions but different carbonate contents in the soil profile. Such distribution is probably associated with different developments of bedrock and different petrographic composition of parent material at the studied localities.

The values of pH reaction correspond to the content of carbonates. Soil profiles of Cikánka and

Table 3 Soil organic matter.

Locality	Depth cm	C_{ox} %	N_t %	C/N	C_{hw} % C_{ox}	C_{hw} mg/kg
Cikánka	0–9	2.61	0.39	6.69	2.41	629
	9–22	2.28	0.26	8.77	2.82	643
	22–45	1.50	0.23	6.52	4.89	733
	45–105	0.53	0.06	8.83	1.53	81
Třesín	0-6	4.60	0.43	10.70	0.33	152
	6–19	2.28	0.18	12.67	0.95	217
	19-56	2.02	0.15	13.47	3.27	660
	56-96	0.99	0.09	11.00	1.84	183
Vyšenské kopce	0–10	4.43	0.44	10.07	6.57	1714
	10–23	2.64	0.32	8.25	3.51	1162
	23–46	2.07	0.22	9.41	2.88	760
	46–80	0.85	0.11	7.73	2.94	421

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

Vyšenské kopce have a slightly alkaline reaction in the upper parts of the profiles and a moderately alkaline one in horizons Crk. By contrast, the values of pH at the Třesín site range from moderately acid and very strongly acid in the upper part of soil to slightly alkaline one in horizon Crk.

Base saturation reaches a value 100 % with the exception of the upper part of soil profile at the Třesín National Nature Monument. Ca^{2+} is the main exchangeable base at all studied sites. Relatively high portion of exchangeable bases Mg^{2+} and K^{+} was documented at the locality of Třesín.

Chemical properties of the studied soils are determined by the variability of the parent material. Carbonate content in soil matrix and parent material influenced chemical properties of the studied Rendzic Leptosols to a higher degree than the different climatic conditions.

SOIL ORGANIC MATTER

The main source of biomass for the process of humification is pine (Cikánka), oak-hornbeam forest (Třesín) and grassland-herbal communities (Vyšenské kopce). The results of the distribution of organic carbon, hot-water carbon, nitrogen and C/N ratio throughout the profiles are presented in Table 3. These parameters were used for the evaluation of the process of humification. The contents of soil organic carbon and nitrogen are the highest in the upper parts of the profiles, but vary among the sites. They are significantly lower at the site of Cikánka. The C/N value showed a different enrichment of soil organic matter by nitrogen. The distributions and contents of hot-water carbon are very different in the individual soil profiles. These results indicate that the process of humification was probably very closely connected with the source of biomass.

PETROGRAPHY OF PARENT MATERIAL

Petrographic observations were made for parent material of the individual soil profiles.

The thin section of a fragment of the rock from the Cikánka site (Fig. 3a) shows calcisiltite of a gravity flow deposit that originated rather in consequence of a slurry flow than a high-density turbidity flow. The 100–600 µm long, thin lamellar bioclasts float in carbonate silt matrix of very fine to medium/coarse sizes with prevalence of particles 5 to 45 µm in size. In the rock, also a diluted dispersion of fragmented crinoid brachial ossicles was observed, as well as small dacryoconarid and other shells. Dissolved sponge spicules together with entrained and embedded fine particles of formerly atmospheric-dust origin left small amounts of silica in the rock.

Very coarse crystalline calcites in brecciated vein fills are the dominant component of rock material at the Třesín locality (Figs. 3b, 3c). The thin section of the rock provides evidence of repeated shear episodes, tectonic brecciation and crack healing. The mm-sized smear-shaped relicts of host rocks appear as ghosts in the crystals and contain small amounts of quartz, silicates and carbon-rich residues. Thin quartz veinlets intersect the Variscan fabrics, occurring later in the succession, but these vienlets were still fractured together with the occurrence of young generations of calcite. The youngest generations of calcite may be Cenozoic in age (O. Bábek, personal communication, 2013).

The rock from Vyšenské kopce (Fig. 3d) is banded to massive in thin section, light grey in colour, and shows medium-grained granoblastic, nearly equigranular textures. Polysynthetic twinning in translucent calcites is mostly straight, rarely bent or disordered; accessory dolomite grains are small and rich in lattice defects and mineral inclusions. Typical accessory minerals of this marble (e.g., phlogopite, graphite, pyrrhotite, dopside and amphibole) can be relatively well indentified under the microscope, because of their common sizes between 50 and 300 µm. The rock contains aggregates optically resembling whitish scapolite or marialite, but dravite crystals potentially occurring together with marialite were not found in the material.

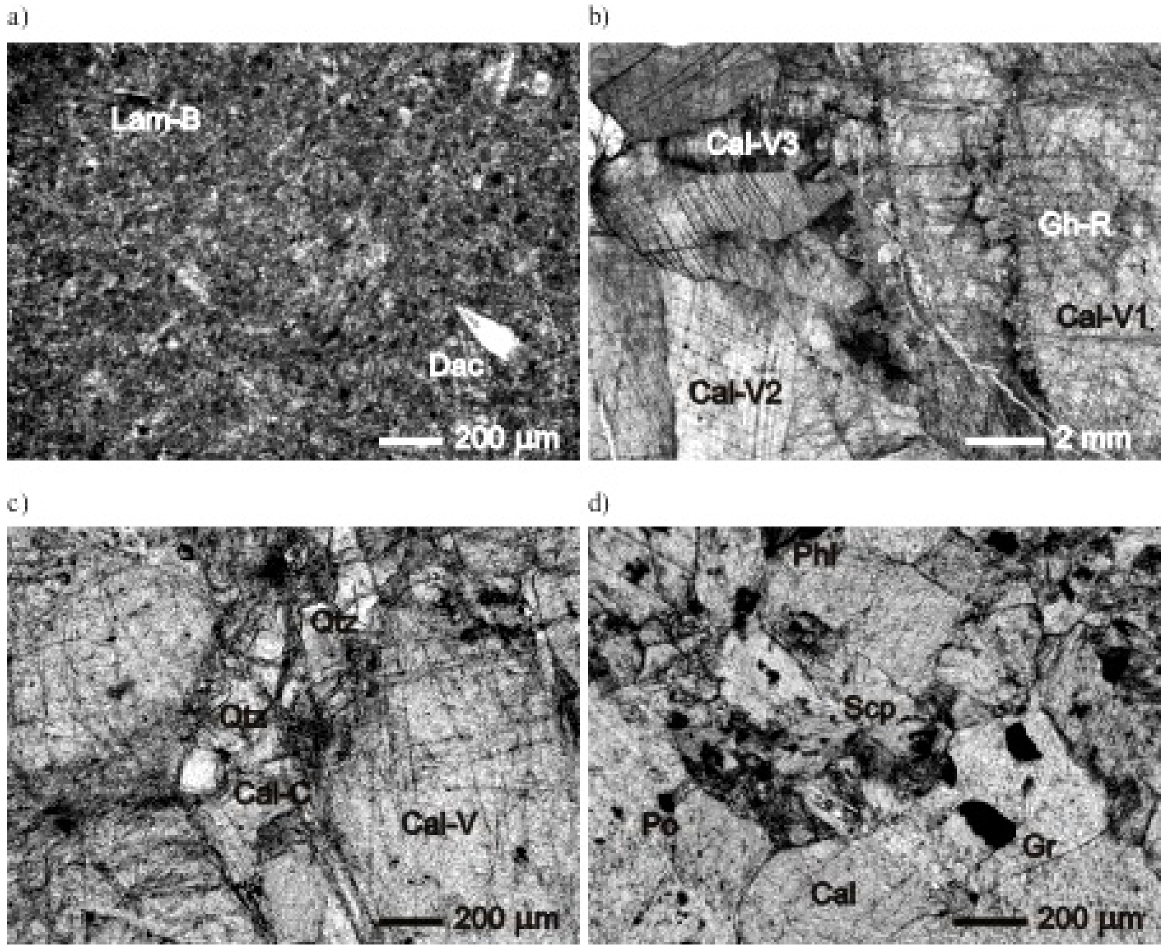

Fig. 3 Microscopic details of thin sectioned carbonate rocks; transmitted white light (Photos J. Hladil).
a) Lower Emsian unmetamorphosed limestone from the Cikánka site. The finest calcisiltite parts of the rock contain diversely directed lamellar bioclasts (Lam–B) which are 'floating' in the matrix together with small fragments of pelagic shells, e.g., a dacryoconarid initial chamber with apical spine (Dac).
b) and c) Brecciated Variscan and younger calcite veins from the Givetian–Frasnian limestone block of Třesín Hill.
b) The oldest Variscan calcite crystals (Cal–V1) have complex record of dynamic recrystallization and contain 'ghosts' of fragmented Devonian host rocks (Gh–R). Younger Variscan calcite crystals show tabular thick twins and are relatively clear (Cal–V2). Calcite of the youngest Variscan generations fills fissures in the central part of the image, with growth direction from right to left, and gradually passes from clear to high-impurity calcite (Cal–V3).
c) A thin quartz veinlet (Qtz) intersecting calcite generations of Variscan age (Cal–V) is brittle deformed, and its fragments are embedded in the youngest generations of calcite which are, most likely, Cenozoic (Cal–C).
d) Medium-crystalline marble from the Vyšenské kopce site. The rock is dominated by calcite (Cal) whereas the dolomite crystals are small and rare, occurring together with other accessory mineral 'impurities' in less translucent areas squeezed among large grains. Rarely occurring scapolite-marialite (Scp) is in the centre of the image, and less translucent and opaque grains of phlogopite (Phl), pyrrhotite (Po) and graphite (Gr) are scattered across the field of the photograph.

Petrography of parent material allows to document local conditions of bedrock formation. Lower Devonian limestones (a transition from the Dvorce-Prokop to Řeporyje facies of the Praha Formation) are the most characteristic types of limestone for the development of Rendzic Leptosol.

MINERALOGY OF PARENT MATERIAL AND CLAY FRACTION OF SOILS

Mineralogy of parent materiál is given in Table 4, and composition of clay fraction in Table 5. X-ray diffractograms of the clay fraction from Ahk_2 horizons are given in Figure 4 (Cikánka), Figure 5 (Třesín) and Figure 6 (Vyšenské kopce).

Table 4 Mineral composition of the rocks.

Locality	Cal %	Ch %	I %	K %	Kf %	Pl %	Qtz %
Cikánka	94	0	1	0	0	0	5
Třesín	97	0	1	0	1	0	1
Vyšenské kopce	47	20	3	6	0	12	12

Cal – calcite, Ch – chlorite, I – illite, K – kaolinite, Kf – K-feldspar, Pl – plagioclase, Qtz – quartz

Table 5 Mineral composition of the clay fraction.

Locality	Depth cm	Am %	Ch %	I %	K %	Kf %	Le %	Pl %	Qtz %	Sm %
Cikánka	0–9	0	5	16	8	5	0	4	62	0
	9–22	0	5	17	7	0	0	4	67	0
	22–45	0	6	25	8	0	0	0	61	0
	45–105	0	5	24	8	5	0	4	54	0
Třesín	0–6	0	3	43	11	9	0	8	26	0
	6–19	2	7	9	0	10	0	12	54	6
	19–56	1	5	18	0	16	2	20	35	3
	56–96	1	0	30	15	11	0	7	27	9
Vyšenské kopce	0–10	16	40	6	0	3	1	5	29	0
	10–23	11	32	6	0	3	1	5	22	20
	23–46	12	44	13	0	0	1	4	26	0
	46–80	0	11	50	0	0	0	2	18	19

Am – amphibole, Ch – chlorite, I – illite, K – kaolinite, Kf – K–feldspar, Le – lepidocrocite, Pl – plagioclase, Qtz – quartz, Sm – smectite

Mineralogy of parent material corresponds to the local conditions of limestone formation. Limestones of very similar compositions were found at the localities of Cikánka and Třesín. Calcite is the dominant component these limestones. Quartz was detected in small amounts. The parent material from the Vyšenské kopce locality shows a high calcite content. The contents of chlorite, plagioclase and quartz are lower. The proportions of kaolinite and illite are very small.

The Cikánka profile is characterized by predominance of quartz in the clay fraction. The contents of illite range from 16 to 25 % and those of kaolinite from 7 to 8 %. These minerals are the insoluble residue of limestone, but at least a small part of their amounts should be assigned to further weathering of micas, alkali feldspar and other silicates in the alkaline conditions (e.g., Egli et al., 2008). The presence of chlorite is slightly smaller (5–6 %), and that of feldspars is slightly higher (8–13 %). The distribution of minerals in the profile indicates stability of soil development.

The clay fraction in the Třesín profile has a higher content of feldspars especially in the Ahk_2 and Ahk_2Crk horizons, which is connected with the limestone-containing flysch sediments. These sediments probably became a part of bedrock due to tectonic changes. In these horizons kaolinite was not determined and the amount of illite is reduced. This soil profile showed lower amounts of quartz than the Cikánka profile. Smectite is absent from the Ahk_1 horizon and chlorite is absent from the Crk horizon. The presence of other minerals such as amphibole and lepidocrocite is very small.

Clay fraction in the profile at Vyšenské kopce is dominated by chlorite except the Crk horizon. The amount of amphibole is relatively high while quartz content is lower. Increased amounts of illite in the Crk horizon result rather from the low degree of chemical weathering. The contents of feldspars range from 2 to 8 %. The amount of lepidocrocite is very small. Kaolinite does not occur at this site. Mineral composition is influenced by the nearby occurrence of amphibolite.

Calcite was not detected in the clay fraction of soils because it was removed in the process of sample preparation. Illite and also chlorite (Vyšenské kopce) are the most characteristic clay minerals of the analysed Rendzic Leptosols.

CONCLUSION

The main soil-forming process in Rendzic Leptosols is humification and subsequent removal of carbonates. Soil formation is limited to the thickness of Ahk horizons. Thickness of this horizon is very similar at all localities. The Ahk_2Crk horizon is better developed at the Třesín National Nature Monument than at other sites. Parent material first occurs between 45 and 56 cm from the soil surface.

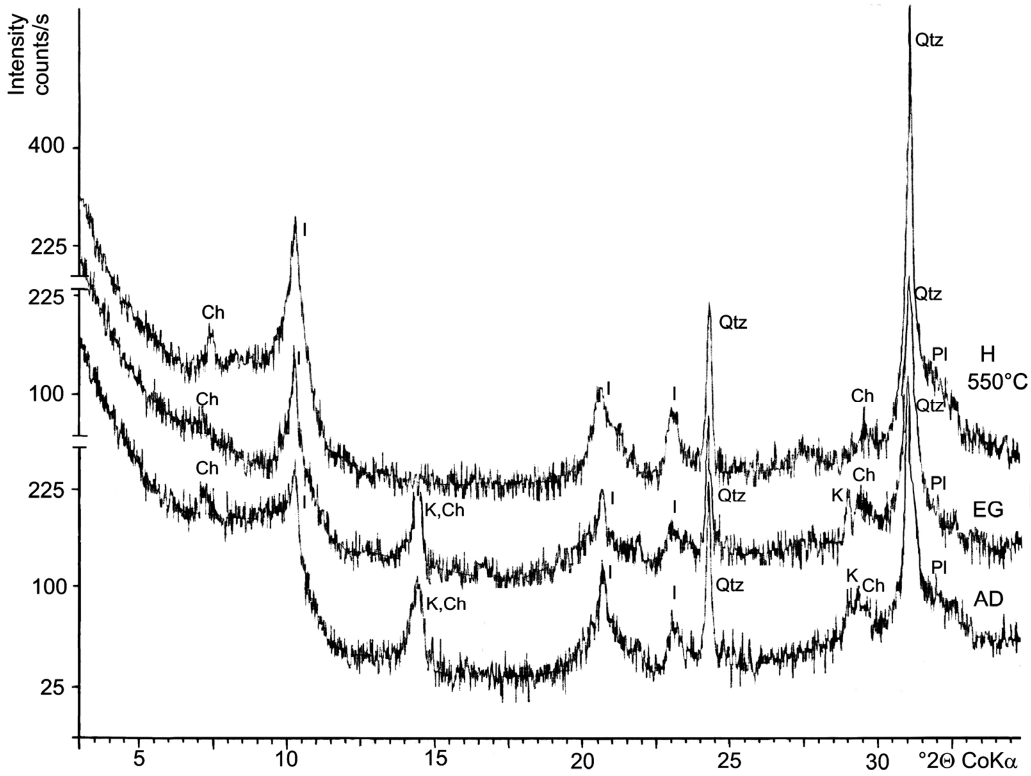

Fig. 4 X-ray diffractogram of clay fraction Ahk_2 horizon from Cikánka
AD – air-dried, EG – ethylene glycol solvated, H – heating, Ch – chlorite, I – illite, K – kaolinite, Pl – plagioclase, Qtz – quartz.

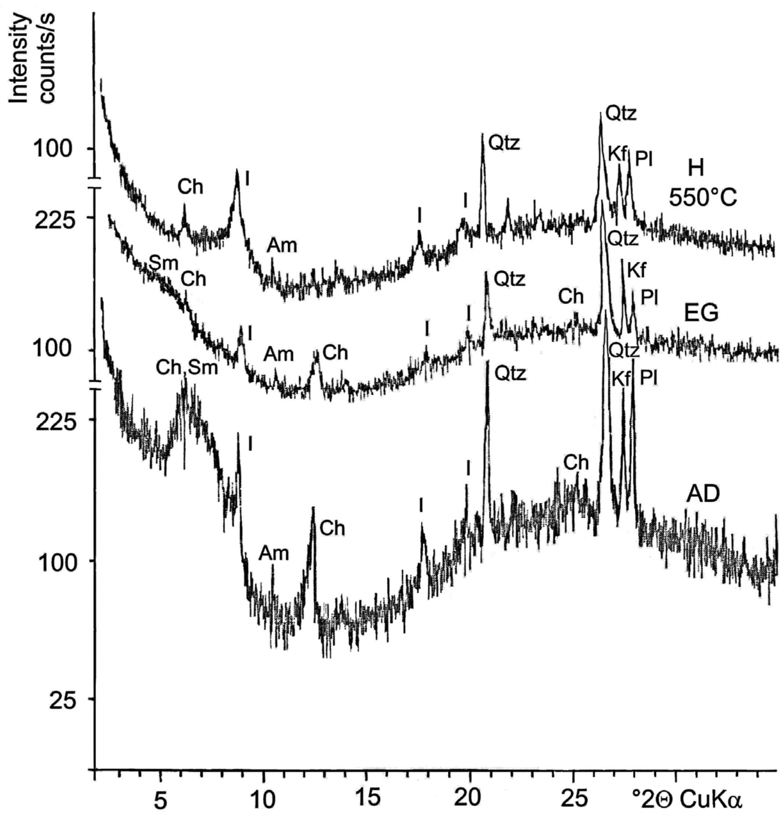

Fig. 5 X-ray diffractogram of clay fraction Ahk_2 horizon from Třesín
AD – air-dried, EG – ethylene glycol solvated, H – heating, Am – amphibole, Ch – chlorite, I – illite, Kf – K–feldspar, Pl – plagioclase, Qtz – quartz, Sm – smectite.

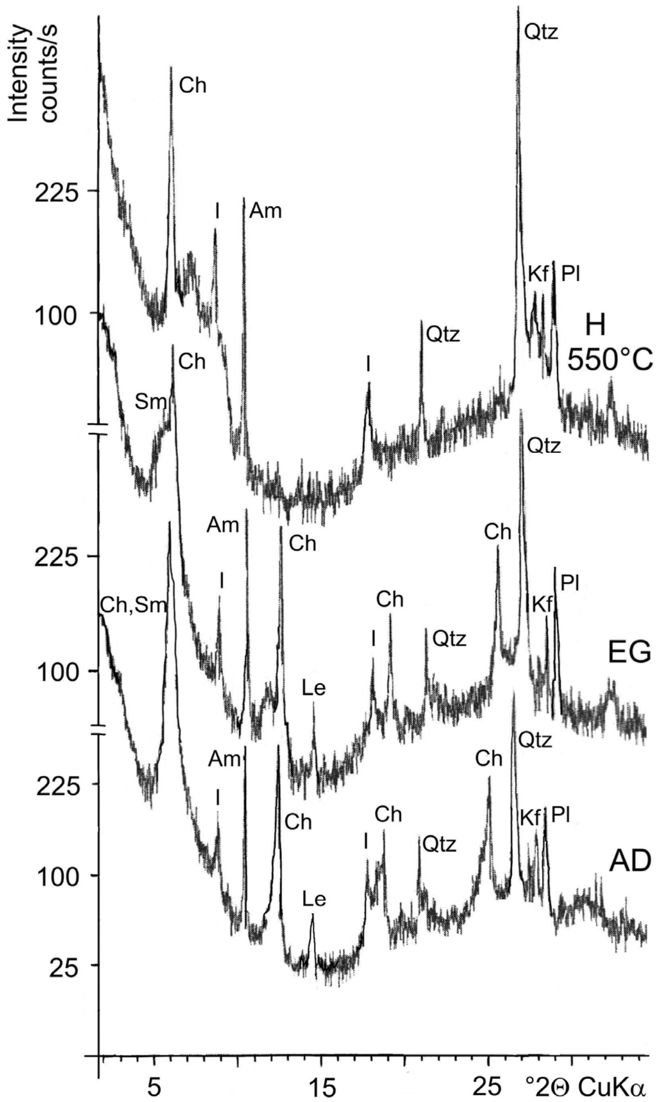

Fig. 6 X-ray diffractogram of clay fraction Ahk$_2$ horizon from Vyšenské kopce
AD – air-dried, EG – ethylene glycol solvated, H – heating, Am – amphibole, Ch – chlorite, I – illite, Kf – K–feldspar, Le – lepidocrocite, Pl – plagioclase, Qtz – quartz, Sm – smectite.

The most characteristic morphological and chemical properties are displayed by Rendzic Leptosol developed on unmetamorphosed Lower Devonian limestones (transition from the Dvorce-Prokop to Řeporyje facies of the Praha Formation).

The particle size distribution, content of carbonates, pH, base saturation and distribution of individual exchangeable cations are controlled by the type of limestone. Removal of carbonates from soil matrix is connected with different development of bedrock at the studied localities.

The intensity of humification and its parameters (C_{ox}, N_t, C/N, C_{hw}) are influenced by the source of biomass and biological activity at the studied sites. Ahk horizons have diverse signs of biological activity. The sites of Třesín and Vyšenské kopce provide more favourable conditions for the process of humification than the Cikánka site.

The mineralogical variability of Rendzic Leptosol is determined by geological settings. Soils developed on limestones of the Moravo-Silesian Zone and the Variegated Group of Moldanubicum have diverse mineral composition.

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