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PARENT MATERIAL AS A KEY DETERMINANT OF SOIL PROPERTIES IN SOUTHERN PART OF NATIONAL PARK KRKA, CROATIA

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ABSTRACT

Parent material is an important factor in soil formation, especially in soils formed in Mediterranean region dominated by calcareous sedimentary rocks. Their basic properties (mineralogical composition, coherence, and permeability for water) influence the resistance to weathering and type of weathering products, its amount, particle size distribution, as well as the intensity of physicochemical transformations within the original rock residue. Thus, the aim of this study was to investigate the impact of parent material on soil properties in southern part of Krka National Park, Croatia. Weathering of carbonate parent material (limestones, dolomites, conglomerates, marls) along with other soil forming factors was the base for soil development in this area. Thus, Calcocambisols and Terra rossa, typical and ilimerized are the most widespread soil types, while Calcomelanosols, Colluvium and Rendzinas are as well represented, but in much lesser extent. Soil depth, presence of coarse fragments and carbonate content in these soils vary considerably depending on parent material, although factors such as relief, vegetation and anthropogenic impact cannot be neglected. In general, shallow soils (< 35 cm) were formed on limestones and conglomerates, while medium deep soils (35-70 cm) were formed on marly substrates. The content of coarse fragments of variable size in soils (fine gravel 2-6 mm to boulders 60-200 cm) is related to different weathering processes of parent material. The presence of carbonate nodules on soil surface and within soil profile also indicates pedogenetic processes related to different types of carbonate parent material.

Key words: *Cambisols, carbonate rocks, soil depth, rock weathering.*

INTRODUCTION

Parent material is one of the crucial pedogenetic factors governing soil genesis (Badia *et al.,* 2013) and affecting soil properties (Burke, 2002; Koojiman *et al.*, 2005; Rodrigo-Comino *et al.,* 2018) especially at the regional scale (Bockheim *et* *al.,* 2005). Mediterranean region is dominated by calcareous sedimentary rocks (limestone, dolomite, marl, etc.) having different characteristics affecting soil formation (Verheye and de la Rosa, 2006). Its mineral composition, rock structure and texture play important role in rock weathering (Pope, 2013), controlling the type of weathering products, its amount, particle size distribution, as well as the intensity of physicochemical transformations within the original rock residue (Verheye and de la Rosa, 2006). Soils formed on carbonate rocks, especially in karst areas, are frequently shallow and highly susceptible to degradation (Moore *et al.,* 2017).

Southern part of Krka National Park is mostly built up from Mesozoic carbonate rocks (CGS, 2009) characterized by high degree of karstification (Perica *et al.*, 2005). Carbonate rocks weathering processes lead to dissolution, disintegration, and accumulation of insoluble residue and organic matter, resulting in formation of reddish soils with high spatial variability (Vrbek and Pilaš, 2007). Thus, the aim of this study was to investigate the impact of parent material on soil depth and selected physical and chemical properties in southern part of Krka National Park, Croatia.

MATERIAL AND METHODS

Situated in the southern part of Krka National Park, study location (Figure 1) is built up from Eocene limestones and carbonate conglomerates ("Promina beds") (CGS, 2009). This area has been intensively faulted and folded forming structures having Dinaric orientation (i.e., NW–SE) and later levelled over a long period of denudation by corrosion planation in the level of the karst water. Karstification of carbonate bedrock resulted in development of karst relief forms (Perica *et al.*, 2005).

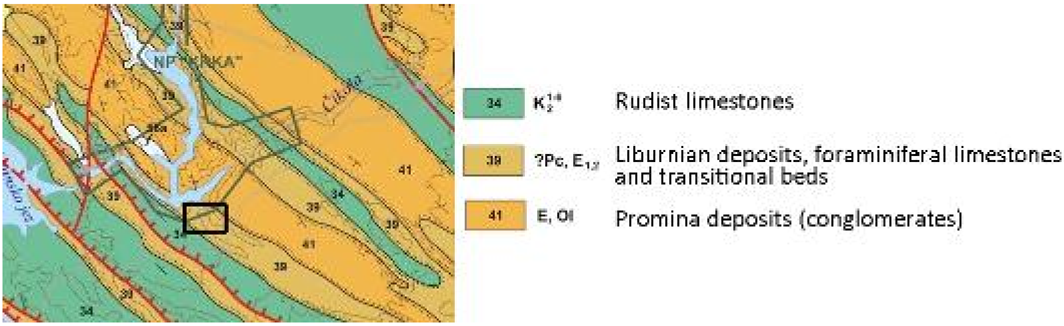

Figure 1 Geological map of study area. Black square indicates location of profiles (CGS, 2009).

The region is characterized by Mediterranean climate (Csa) with dry and hot summers and mild rainy winters (Filipčić, 1998). The mean annual temperature measured at meteorological stations Drniš and Šibenik during 1961-1990 period was 12.9 °C and 15.1 °C, while average annual amount of precipitation was 1063.2 and 808.1 mm respectively (Milković and Trninić, 2007). Accordingly, typical

Mediterranean vegetation dominates the region, characterized by heavily fragmented and degraded downy oak and oriental hornbeam forest (*Querco-Carpinetum orientalis H-ić 1939*) (Medak and Perić, 2005). On sparse agricultural plots grape vine (*Vitis vinifera*), olives (*Olea europaea*), figs (*Ficus carica*) and almonds (*Prunus dulcis*) are cultivated. According to the Basic pedological map of Croatia 1:50 000, section Šibenik 1 (Čolak and Martinović, 1975) dominant soil types on study area are: Calcocambisols, and Terra rossa, with less represented Calcomelanosols, Colluvium and Rendzinas.

Four study sites were selected to exemplify the most common parent material and soil types of the study area. Profile P-1 is developed on conglomerates; P-2 and P-3 on limestones, while P-4 on marly limestones. Field description of soil morphology and coarse surface fragment content followed FAO guidelines (FAO, 2006). Laboratory analyses were carried out by following methods: particle size distribution (ISO 11277:2009), pH (ISO 10390:2005), humus content (Tjurin method, JDPZ, 1966) and total carbonate content (ISO 10693:2004).

RESULTS AND DISCUSSION

Parent material at the study site is build up from Eocene conglomerates and limestones. Conglomerates are poorly sorted, clast supported with pebbles up to 2 cm in diameter, having variable sphericity. These are composed of Cretaceous and Paleogene limestones, granular dolomites, dolomitized radiolarian cherts and fossil fragments. Although outcrops mostly have massive appearance, weathering propagates along grain edges, causing disintegration of rock (while grains remain mostly intact). Limestones on the other hand are mostly detrital, fine-grained, and often alternate with marls or marly limestones with microcrystalline to cryptocrystalline structure. These rocks are subject to intense karstification process, causing rock weathering.

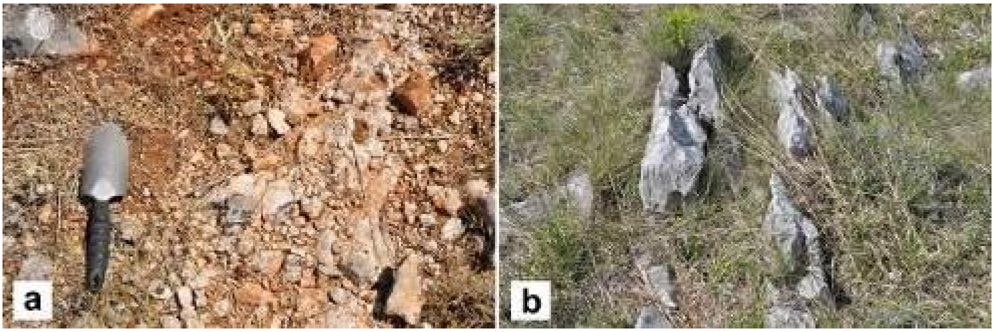

Figure 2. Typical appearance of rock outcrops a) conglomerates, b) limestones.

Described differences of parent material reflect in style of rock weathering, resulting in distinct properties of the soils develop on top (rockiness, soil depth, physical and chemical properties).
Surface of P-1 profile developed on conglomerates is characterized by having few rock outcrops (2-5-% with distance between rock outcrops 20-50 m), while surfaces of profiles developed on limestones (P-2 and P-3) and marly limestones (P-4) have many rock outcrops (15-40% with distance between rock outcrops 2-5 m; FAO, 2006). Furthermore, abundance and size of coarse surface fragments of analysed profiles as well depends on parent material (Figure 2). Conglomerates (profile P-1) have abounded amount (40-80%) of surface fragments, which size is mostly fine gravel (0.2-0.6 cm) and medium gravel (0.6-2 cm), while coarse gravel (2-6 cm) and stones (6-20 cm) are as well present. Profiles P-2 and P-3 developed on limestones have many (15-40%) coarse surface fragments, both being dominated by coarse gravel fraction, where medium gravel and fine gravel are present in P-2 profile, while P-3 profile contains stones and boulders (20-60 cm) fraction. Surface of P-4 profile developed on marly limestones has common (5-15%) surface fragments of larger size classes (boulders and large boulders; 60-200 cm). Determined surface rockiness and abundance and size of coarse fragments are in agreement with studies done in the region (Čolak and Martinović, 1975; Vrbek and Pilaš, 2007).
Soil depth is closely related to weathering processes of parent material (Koojiman *et al.,* 2005; Vrbek and Pilaš, 2007; Badia *et al.,* 2013; Perković *et al.,* 2017), thus studied soils vary from shallow (<35 cm) to medium deep (35-70 cm). Thickness of soil cover varies from 11 cm (P-1, conglomerates), over 17 cm (P-2, limestones), and 38 cm (P-3, limestones), to 66 cm (P-4, marly limestones). This can be attributed to weathering style of parent material and erosion. Thus, weathering of conglomerate rocks propagates along grain boundaries, causing detachment of clasts of different sizes which are accumulated on the surface, while fine fraction is probably eroded by water or blown away. Weathering of the limestones and marly limestones results in accumulation of insoluble residue which is a basis for soil development. These particles as well can be blown away, but rough morphology of limestone outcrops can act as a trap for sediments, where deeper soil outcrops are often found in fissures formed by karstification process (Bogunović *et al.,* 2009). Thus, profiles P-1 and P-2 have only one horizon A/B developed, profile P-3 has A and Bw horizons, profile P-4 has horizons A, Bw, Bt and Bk (FAO, 2006; Figure 3 a-d).
Analysed soil profiles mostly have clayey texture (Table 1) typical for these soil types (Durn 1999, Bogunović *et al.,* 2009, Vrbek and Pilaš, 2007, Vingiani *et al.,* 2018) having clear increase of clay content with depth.

Figure 3. Soil profiles on different parent material a) P-1 Terra rossa on conglomerates b) P-2 Terra rossa on limestone c) P-3 Calcocambisol on limestone d) P-4 Calcocambisol on marly limestones.

Table 1. Particle size distribution and texture classes of analysed soil profiles

Soil profile/horizon	2-0.2 mm	0.2-0.063 mm	0.063-0.02 mm	0.02-0.002 mm	<0.002 mm	Texture class
P-1/ A/B	2.9	2.7	36.5	26.3	31.6	Silty clayey loam
P-2/A/B	2.3	3.3	65.2	10.9	18.3	Silty loam
P-3/ A	1.8	3.6	34.9	37.0	22.7	Silty loam
P-3/ Bw	2.0	3.7	31.0	18.5	44.8	Silty clay
P-4/ A	4.5	6.1	18.0	24.1	47.3	Clay
P-4/ Bw	2.8	5.6	14.1	19.1	58.4	Clay
P-4/Bt	1.7	4.7	10.2	12.2	71.1	Clay
P-4/Bk	10.7	7.2	17.1	14.2	50.7	Clay

The soil reaction of analysed soils is weakly acid to alkaline (Table 2) depending on the presence of carbonates. Profiles P-1, P-2 and P-3 are non-calcareous throughout entire depth, indicating dominant chemical weathering of parent material, dissolution of carbonate sedimentary rocks and accumulation of insoluble residue, Table 2. Weakly acid reaction and absence of carbonates in soil profile is reported in many studies of Terra rossa (Škorić *et al.*, 1987; Miloš and Maleš, 1987; Temur *et al.*, 2009; Vingiani *et al.*, 2018) and Calcocambisols (Bogunović *et al.*, 2009; Vrbek and Pilaš, 2007).

Table 2. Soil reaction, carbonate and humus content of analysed soil profiles

Soil profile/horizon	pH		$CaCO_3$ %	Humus %
	H_2O	KCl		
P-1/ A/B	6.9	6.5	0.0	6.4
P-2/A/B	7.0	6.5	0.0	8.1

P-3/ A	6.9	6.5	0.0	7.4
P-3/ Bw	6.9	6.5	0.0	6.9
P-4/ A	7.0	6.6	3.9	9.1
P-4/ Bw	6.1	5.1	0.0	5.8
P-4/Bt	6.5	5.3	0.0	3.0
P-4/Bk	8.0	7.2	20.3	1.4

The carbonates present in profile P-4 in A horizon could be attributed to calcareous wind –blown particles. Carbonates are as well presented in the lowermost part of this profile (20.3% in Bk horizon) in a form of spheroidal nodules, few millimetres in size, that can be result of re-precipitation of dissolved $CaCO_3$ from underlying carbonate parent material. Furthermore, presence of carbonate rock fragments in this horizon indicates physical weathering of marly limestones.
Analysed soils have low to medium humus content (Table 2) depending on vegetation (amount of biomass) that is indirectly related to soil depth. The highest humus content was measured in the thickest soil profile (P-4), where values decrease with depth. Similar results were obtained in studies of cambic soils on carbonate parent material in Mediterranean area (Miloš and Maleš, 1998; Bogunovć *et al.*, 2009; Vrbek and Pilaš, 2007; Vingiani *et al.*, 2018).

CONCLUSIONS

Parent material is an important factor in soil formation, impacting rock weathering style, type and amount of weathered material and consequently properties of the soils developed on top. Study area is built of conglomerates, limestones and marly limestones of Eocene age, characterized by high degree of karstification. Soils developed on conglomerates are shallow, having few rock outcrops and abundant coarse fragments (having fine and medium gravel size). Limestones have many rock outcrops and coarse fragments of coarse gravel size. Finally, soils on marly limestones are medium deep and have many rock outcrops, where coarse fragments are common and of larger size. Analysed soils have uniform clayey texture and variable chemical properties (pH, $CaCO_3$ and humus content) indirectly related to different weathering processes of carbonate parent material.

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