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Sedimentological and mineralogical characteristics of red soil in South Pirin Mountains (Southwest Bulgaria)

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Abstract: The northernmost derivation of the Mediterranean climatic influence and the wide distribution of carbonate rocks are factors that could explain red soils distribution in the lands of Southern Bulgaria. However, due to the mainly mountainous landscape, red soils can be found only on certain spots in Bulgaria. One of the most typical examples of red soil can be found in the lands of Nova Lovcha Village in Bulgaria, but this area was not studied in detail due to its border position. In this study, the catena principle was used to estimate the parental material and slope drainage relationships as factors in soil formation. Samples from different parts of the slope were analyzed for grain size, parent rock and soil mineralogy, pH, and humus content. The red soils of Nova Lovcha showed both local rocks origin in the deeper parts of the soil profiles and allochthone silicate elements in the upper horizons. The most relevant explanation for this mineralogical difference could be a transfer from another nearby area; Neogene alluvial deposits or from weathered older rocks, cropping out in the vicinity of the area. Our results show a relation between this particular landscape and the Greek Thracian allochthonous red soils. This confirms the variety of factors for red soil formation and explains the penetration of Mediterranean influence in the mountains of the Balkan Peninsula.

Key words: Mediterranean red soils, grain size, parent rocks mineralogy, X-ray powder diffraction, Nevrokopean Neogene basin, South Pirin

1. Introduction

The origin of the red Mediterranean soils is disputable among the pedologists and geomorphologists as a result of the inner metamorphic processes in the parental limestones (e.g., Reifenberg, 1947; Dudal et al., 1966, and many others), and/or slope wash processes (Glazovskaya and Parfenova, 1974), and/or aeolian origin of allochthone microelements downwards the soil layers, all developed under Mediterranean influence on the climate and biota. Apparently, the local differences along the Mediterranean are so many that it is not possible to point out one clear reason to unify one red soil type in the whole area, and the idea about the Mediterranean Terra Rossa was abandoned (Yaalon, 1997).

Southern Bulgarian territory is part of the northernmost derivation of the Mediterranean climatic influence in Eastern Europe. This, together with the wide distribution of carbonate rocks, the same as those in the Mediterranean, determines red soil formation to be expected. However, mountainous landscape in the region complicates the soil formation factors. Currently red soils in Bulgaria can be found at certain spots, related to carbonate rocks or slope-washed material next to them. They are defined as three soil types, according to the FAO's system: Chromic Cambisols, Rendzic Leptosols, and Rhodic Nitisols (Ninov, 2002). It is believed that they are formed under warm and humid conditions (could be in ancient times) on slight slopes. There are also few places in Bulgaria with described red soils on silicate parent rocks: red sandstones and clayish schist, where the color is explained (Pushkarov, 1913) by the increased iron content in the soil. As Ninov (2002) emphasized, "the area of red and yellowish soils is the most interesting "oasis" in Bulgaria, in the Balkans, and in Europe with its numerous relict and Southern Euxinian floral elements and forest vegetation, as well as specific weathering of parent rock and development of inner elementary soil formation processes—alitization, ferritization, and rubification".

This study's interest was pointed at the area of the border territory of Bulgaria and Greece, between the slopes of South Pirin (from the North–Northwest), Slavyanka

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Mountain (from the South–Southwest) and Stargach Mountain (from the East). It was inspired by the soil's red color (5YR 3/4 dark reddish brown in the top layer and 2.5YR 4/8 red in the deeper layers) observed on flat sections of the Nova Lovcha Village lands and in the lands on the other side of the border in Greece (Figure 1). Because of the close location to Greece, connection with the red Mediterranean soils was expected. To date, this territory has been very poorly studied because of the border position and the low-populated mountainous terrain with limited farmland.

Studies of soils in Greece (Yassoglou et al., 1997; Haidouti et al., 1997, 2001) showed parallels with the Greek Thracian allochthonous red soils, distributed on the Tertiary and Pleistocene surfaces of the lowlands in the thermo- and meso-Mediterranean bioclimatic zone (UNESCO/FAO, 1963). The studied soils (Yassoglou et al., 1997; Haidouti et al., 2001) were developed on Quaternary calcareous deposits, located on several geomorphic surfaces on moderately to gently sloping landscapes. According to the USDA classification (Soil Survey Staff, 1998) used in the survey, these soils were classified as Alfisols in the great group of Rhodoxeralfs.

The aim of this study was to present the results from sedimentological and mineralogical characteristics of the red soil in this particular landscape in Bulgarian territory and to compare its origin and formation with similar examples along the Mediterranean.

2. Regional setting

The parental rocks in the study area are dominantly metacarbonates (marbles) referred to as the formal lithostratigraphic unit Dobrostan Formation (Kozhouharov, 1984). The rocks in this unit are defined as white sugar-like marbles and gray-striped marbles. They show granular texture and are composed of calcite and dolomite, as the dolomite component is often dominant. In Nova Lovcha area, the marble breccias from Paril Formation (Zagorchev, 1995) are also present. The breccias are composed of angular and subangular marble pieces from Dobrostan Formation in a clayey-carbonate matrix.

The relief is ranging in altitude from 700 m to 1006 m. The state border with Greece crosses a flat watershed between two catchments with reverse direction. In Bulgarian territory, the catchment of Matnitsa River, tributary of Mesta, is drained northwards and in Greece begins the catchment of Vatipopu River, drained southwards (see Figure 1). However, the whole landform (covered with the same red soils in Bulgarian and in Greek territory) appears as one negative structure, in which the two valleys take different courses without any obvious reason. This intermountain basin is covered with Quaternary alluvial sediments and in the northern part are exposed the Neogene sediments of Nevrokop Formation (Kozhouharov and Marinova, 1991). According to previous paleogeographical studies (Choleev and Baltakov, 1989; Psilovikos and Vavliakis, 1989; Vatsev, 1991; Baltakov et

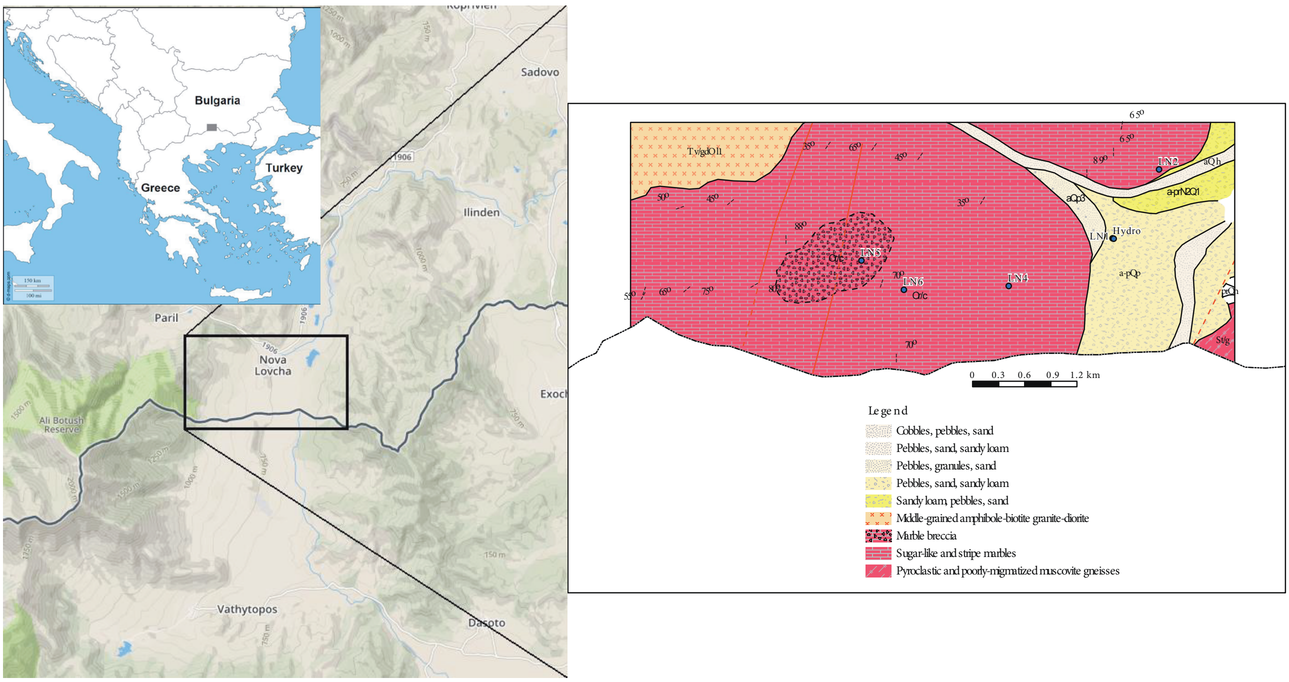

Figure 1. Location of the studied area and reference to the petrographic units on Bulgarian territory (after Kozhouharov and Marinova, 1991).

al., 2000) of the region during the Neogene, the little valley of Nova Lovcha was a link between two large basins: Upper Nevrokopean (after the former name of the town Gorni Nevrokop, today Gotse Delchev in Bulgaria) and Lower Nevrokopean (after the name of the town Kato Nevrokopi in Greece), drained in the Plio-Pleistocene.

Soils formed on the marbles in the area of Rhodopeans are defined as Chromic Cambisols in the accumulative parts and Rendzic Leptosols on the slopes (Ninov, 2002).

According to the climatic data (Kjuchukova, 1979, 1983; Koleva and Peneva, 1990; Nikolova and Rachev, 2009) and our data, the climate conditions in the study area are Mediterranean with strong mountainous influence. For the last 80 years in the area of Nova Lovcha, the average values have been as follows: air temperature, 11.3 °C; rainfall, 633 mm; and humidity, 72%. In the period of our observations (2011–2013), the maximum precipitation was in February (136 mm) and May (106 mm) and the minimum was in June–August (29–41 mm). The lands of Nova Lovcha have eastern exposure and thus is under the influence of a rain shadow from the path of the Mediterranean cyclones with dominantly western direction.

Biodiversity also reflects the transitional character of the area. However, the Mediterranean species are an exception, because of the mountainous terrain. This territory is classified by Asenov (2006) as the southern border of the Balkan Highlands biogeographic province with a prevalence of oak trees (formations *Quercus pubescens* and *Quercus virgiliana*) with an involvement of hornbeam (*Carpinus orientalis*) and Mediterranean shrubs in the lower parts. Upwards areas with black pine (form. *Pineta nigrae*) and sessile oak (*Quarceta dalechampii*) are preserved. From the bushes, form. *Paliureta spina* is involved in all over the communities or even forms individual colonies. On the slopes, the grass formations are common: form. *Dichantieta ischaemi*, *Chrysopogoneta grylli*, *Brometa madritensis*, *Cariceta spicatae*, *Agrostideta capilaris*, *Poaeta bulbosae*.

3. Materials and methods

The catena principle (Scheidegger, 1986) is used to estimate the local conditions for soil formation (the parental material and slope drainage relationships) along a single slope section. The catena (lat. "catenae": chain) concept was originally proposed by Milne (1935) in research of the soil types connected with specific locations on the slopes. It is adopted by Scheidegger (1986) for self-repeating morphological features, such as eluvial-colluvial-alluvial zones on slopes.

The different types of marbles and above-formed weathered products and soils are sampled at different parts of the slope in the lands of Nova Lovcha:

1) The convex part (sample LN 5), which presents the source area. The slope inclination is ascending from 3°–4° to 8°, build of superficially weathered marbles with rough terrain and fragment soil cover developed in the grykes (Figure 2a).

2) The middle straight part (LN 6 and LN 4) with dominant transport processes: leaching and sheet erosion. The soil cover is fragmentary developed in the fissures, where the leaching is in progress (Figure 2b);

3) The concave lower slope part (LN 1), where the accumulation of the washed slope materials is prevailing (Figure 2c).

The thickness of soil profiles is 5–40 cm with weathered coatings 2–20 cm, and in the accumulative plane up to 200 cm with 90 cm weathered materials. A distinct weathered crust is observed, but soil profiles are not clearly defined. A geophysical survey (Yaneva et al., 2012) confirms the following soil profile composition:

1) clayey layer (0–110 cm),

2) weathered and fractured parent rock (110–202 cm), and

3) parent rock below 202 cm.

The soil sampling included excavation of profiles on hill slopes or hand drilling in accumulative planes depending on the geomorphic features of the site. The four profiles with totally 12 layers were analyzed by the following procedures.

(a) (b) (c)

Figure 2. Sample sites at different parts of the slope: a-convex part; b-middle part; c-concave part.

Grain size was measured using sieve analysis by equipment Vibratory Sieve Shaker ANALYSETTE 3 PRO and pipette analysis (Folk, 1974) for the fraction less than 0.02 mm. The suspension was placed in 1l cylinder and fractions of sizes less than 0.016, 0.008, 0.004, 0.002, and 0.001 mm were withdrawn at certain time intervals based on Stokes' law. Comparison of soil texture data from previous studies is rather difficult because of the previously used Kachinsky scheme soil grouping (Kachinsky, 1965), based on the two parameters: physical clay particles (<0.01 mm) and physical sand particles (>0.01 mm). We used the parameter <0.01 mm fraction in order to compare the results we obtained in our research with the soil texture parameters of other soils in Bulgaria.

Mineralogical composition of soil was identified by X-ray powder diffraction (XRD) using TUR M62 Diffractometer, Cofiltered irradiation. Grain-size fraction between 63 and 125 µm is divided to light and heavy fraction by Bromoform (CHBr3, 2.93 g/cm^3). The mineral fractions from weathered materials and soils were submitted to mineralogical analyses under polarizing microscope in immersion Eugenol (refractive index ne = 1.541). Quantitative evaluations were made on the basis of minimum 400 grains of the light fraction and 500 transparent grains of the heavy fraction.

Soil samples are also analyzed for pH and humus content (in %).

3. Results

Parameters of all samples are summarized in Table and Figure 3. Regarding grain size, the following characteristics were observed:

- Logically, the coarser grains are situated in the upper parts of the catena, where the gravel fraction is almost 50% (the superficial layer of LN5).
- The finer fractions are prevailing in the depositional parts of the catena (LN1 and LN4), where the silt content is ascending downwards in the profile and the clay content is descending in the same direction.
- Fraction ≤0.01 mm in the deepest profiles (in accumulative parts of the slope) is higher than 60%, which makes these soils the most clayey in Bulgaria.

Humus content (in %) is descending downwards along the catena profile and in deep in the lower soil profiles LN4 and LN1. Higher humus content in the upper parts of the catena (LN6) could be explained with the undecomposed or partly decomposed organic matter in the forest litter. Unlike the forests, the humus content in the soil litter beneath scrubs and grass (LN5) is triple less and in farmlands (LN4 and LN6) is almost twice less. A study of the humus (Sarafov and Filcheva, 2014) shows that the humic acids prevail over fulvic acids content in LN4 and LN1. The same authors defined the soil system in these profiles as stable and that the soil has good physical and chemical characteristics.

Regarding the soil pH, the reaction is alkaline with slight differences along the catena profile.

On the slope (LN6 and LN5) it reaches 8.75 and at the accumulative parts, it is almost 8. In profile LN1, logically the layers become more alkaline in depth.

Deposits and soil colors vary from brownish gray and yellowish brown on the slope to reddish brown at the superficial layers of accumulative parts and red in depth.

Mineralogical composition shows the following characteristics:

Table. Soil parameters along the catena.

Profiles		Grain size (fractions in %)						color	humus %	pH
		64–4 mm	4–2 mm	2–0.62 mm	0.62–0.004 mm	>0.004 mm	≤0.01 mm			
LN 5	A′ 0-10	46.04	6.24	32.79	4.80	10.14	6	10YR 6/2	1.89	8.6
	A″10-20	23.53	7.8	50.22	2.40	16.05	7.2	10YR 6/2	1.63	8.75
LN 6	AC 0-10	21.06	5.12	19.55	19.20	35.07	28.8		5.58	8.01
LN 4	A 0-20	-	0.21	15.09	41.40	43.20	72	2.5YR 3/4	3.09	8.10
	A_2 20-40		0.16	2.44	32.2	65.19	54	2.5YR 2.5/3		-
	aB_1 40-50		0.12	4.28	14.00	81.60	44.8	2.5YR 2.5/3	-	-
	B_2 50-80			1.82	19.20	78.98	26.4	2.5YR 3/6	0.75	7.86
LN 1	A 0-20		0.23	10.10	35.20	54.45	46.88	5YR 3/4	3.29	7.87
	A_2 20-50		0.03	4.46	27.84	67.67	43.72	2.5YR 4/8	0.9	7.96
	B 50-110			1.68	25.60	72.72	64	2.5YR 3/6	1.07	7.91
	C 110-202	0.74	0.39	63.77	5.96	29.14	9.88	5YR 5/8	<0.1	8.34

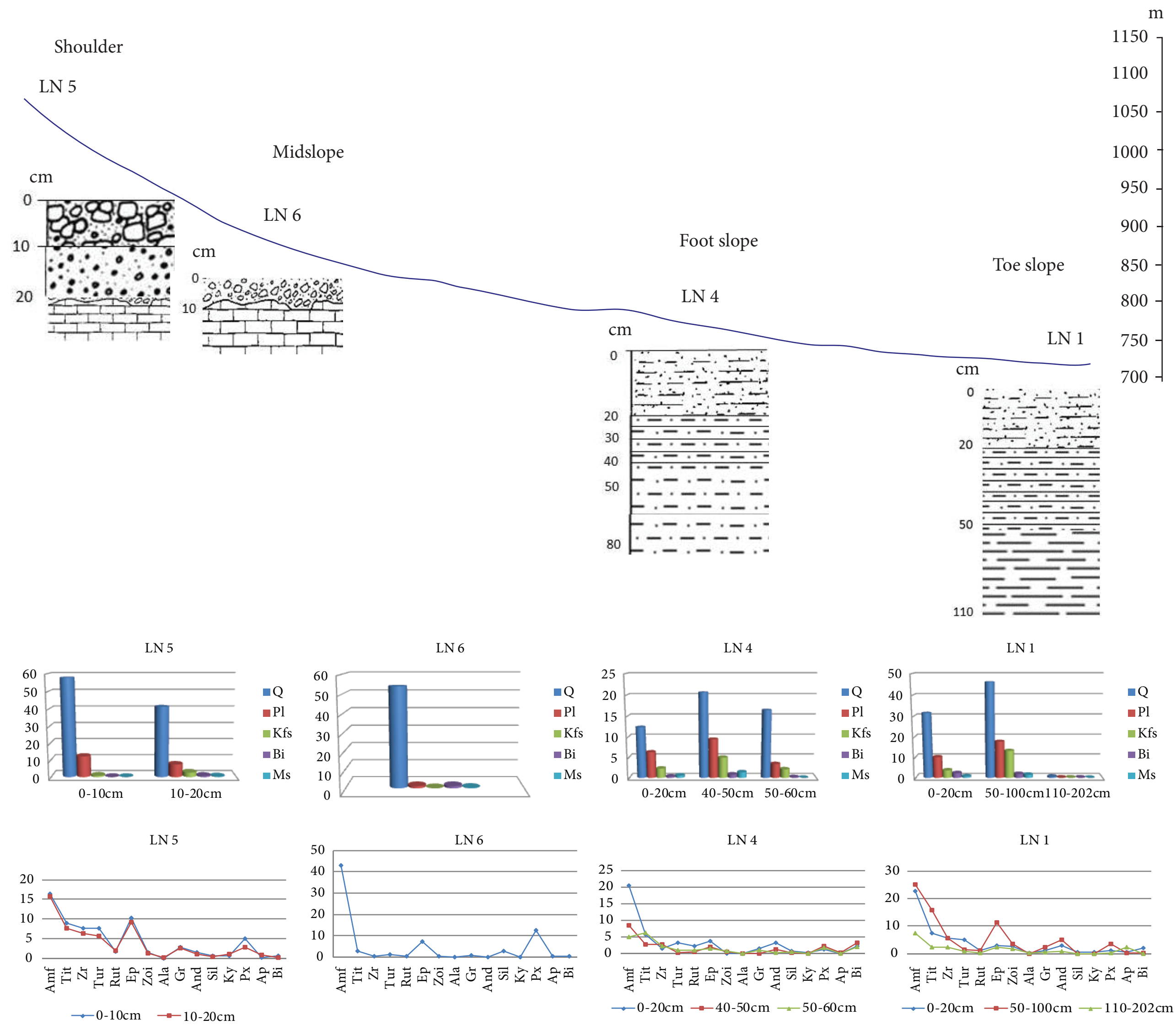

Figure 3. Distribution of minerals in light and heavy fraction 0.063–0.125 mm in soil profiles from Nova Lovcha.

Common composition in all soil profiles; quartz and carbonates are dominant in the group of light minerals (Figure 3), followed by plagioclases and potassium feldspars, and micas are in insignificant quantity. Plant tissues and pollen grains represent about 7%–8%, up to 70% of the light fraction. Carbonate content (calcite and dolomite) increases gradually downwards in the soil profiles. Samples from the slope shoulder in LN5 contain dominantly quartz and calcite, and insignificant amount of feldspars and illite type mica. At the midslope in LN6, mineral composition is represented by quartz, calcite and dolomite, and feldspars are just traces (about 1%).

Deposits in the foot slope and toe slope parts show similar mineral compositions (quartz, plagioclases, potassium feldspars, mica, kaolinite, montmorillonite, illite, calcite, and dolomite). The toe slope profile is more abundant in detrite minerals than the foot slope. Heavy fraction is represented chiefly by iron oxides and hydroxides (goethite and hematite) and amphibole, followed by epidote minerals, pyroxene, titanite, zircon, tourmaline, garnet, and also apatite, kyanite, andalusite, and sillimanite as accessory minerals. In all profiles along the slope, the amphibole-epidote-pyroxene association is dominant (Figure 3).

· The results from powder X-ray diffraction (Figures 4 and 5) showed variable mineral composition: dominantly kaolinite and quartz, less plagioclase and insignificant quantity hydromica of illite-muscovite type (Yaneva et al., 2014).

· The results suggest origin close to the parent rock: calcite and dolomite in profiles LN 5 and LN 6. For accumulative profiles LN 1 and LN 4, the composition

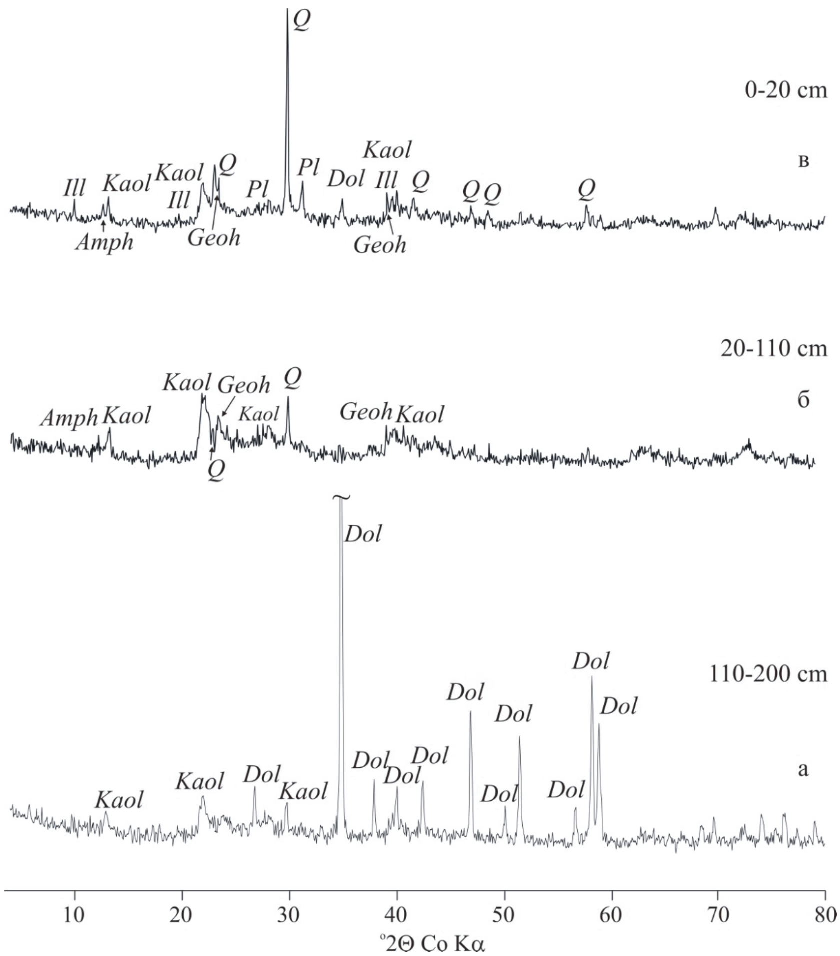

Figure 4. X-ray powder diffraction patterns of soils formed above white dolomite marbles in Nova Lovcha.

is strongly influenced by weathering products from the Neogene alluvial deposits and from the matrix of the marble breccia of the Paril Formation.

4. Discussion

The results suggest definitive differences in slope materials origin along the catena profile. At the upper part and of the slope (LN 5 and 6 LN) mass movements depend on the grass cover density—sheet washing is typical on the grass islands; on the rock outcrops, the weathered materials are falling and form scree fans. Soil cover at the slope shoulder is very thin and rocky, with indistinguishable mineral and chemical changes; thus, we define the deposits at LN5 as regolith.

At the midslope parts (LN 6), we observe an increased amount of fine fractions. Grain size together with the light color and undecomposed or partly decomposed organic matter suggests in situ weathering of marbles and shallow soils formation. In the forest zone, soil cover and forest litter accelerate weathering in depth and this is evident in the increased amount of the fine fraction and the presence of clay minerals. The color and humus in the forest zone (LN 6) become yellowish. Regarding their sandy–clayish composition, we associate the soils of LN 5 and LN6 as Calcaric Regosols (according to FAO classification).

In the foot slope (LN 4) and toe slope (LN 1) parts of the catena, soil profiles become more developed. Mechanical composition abruptly changes in the direction of increasing silt fraction in the complete absence of gravel and presence of few granules. The content of mud fractions in both profiles characterizes them as coarse, medium, and fine sandy loam to coarse and medium loam. From the mechanical structure aspect, we divide the profiles into two: A-humus horizon and B-transitional horizon. Unfortunately, field description and sampling of LN 4 reached only 80 cm, whereas the depth of LN 1 exceeded 200 cm. The lowest horizon in the last profile is part of in situ weathering crust. This is confirmed by all the collected data and a geophysical study. Layers above have characteristics of in situ deposits (decreasing in size

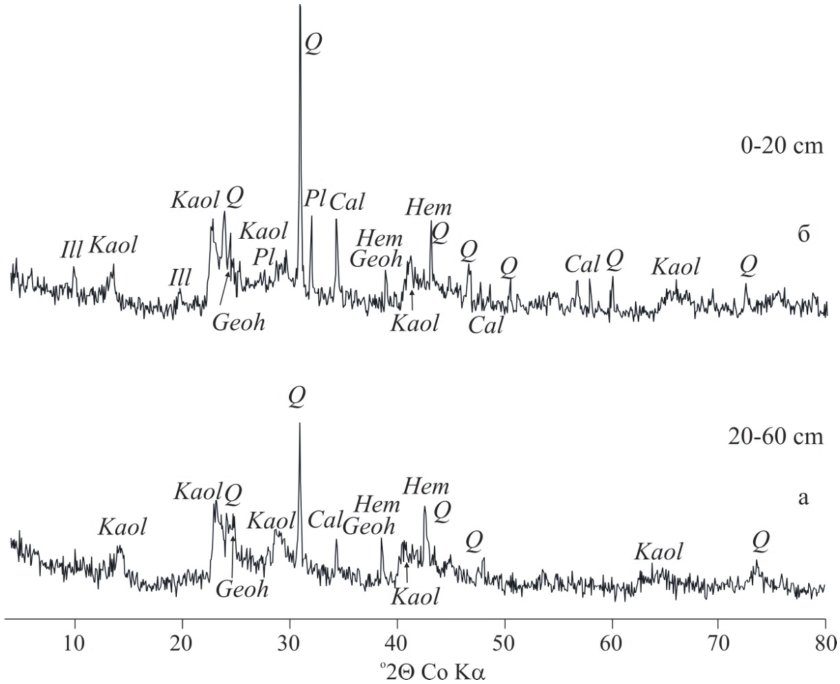

Figure 5. X-ray powder diffraction patterns of soils formed above gray-striped calcite marbles in Nova Lovcha.

fractions, red color, significant amount of kaolinite) and allochthone materials—silicate minerals in the heavy fraction 0.063–0.125 mm. Their presence could be due to transfer from another nearby area—Neogene alluvial deposits of Nevrokop Formation (Yaneva, 2002; Yaneva et al., 2002) or from weathered older rocks, cropping out in the vicinity of Nova Lovcha. On the other hand - a small quantity of them is in the marbles and their significant accumulation could be due to the long term weathering process. The whole discussed profile LN 1 in the general surveys (Ninov, 2002) is referred to as the group of Rhodic Nitisols (according to FAO classification). As mentioned before, similar soils in Greece were classified as Alfisols in the great group of Rhodoxeralfs (Yassoglou et al., 1997; Haidouti et al., 2001) according to the USDA classification.

5. Conclusion

The case study in the vicinity of Nova Lovcha in the South Pirin Mountains (SW Bulgaria) was conducted in a poorly known border area. It is part of mountainous region, typical of the Mediterranean, dominated by landscapes with steep slopes and relatively narrow valleys. An obvious consequence of the prevalence of steep slopes is relatively rapid erosion. As a result, in the higher parts, shallow and weathering-limited, regolith and soils could be observed except on foot slopes. Accumulated slope sediments and valley fills are related to environmental changes and river shifts from the Quaternary to historical times. In this aspect, as the other examples of red soils in Bulgaria, this particular case confirmed the complicated, including paleoenvironmental origin of the red soils in Nova Lovcha vicinity and the strong relation with the Rhodopean region development. Without any doubt, parental materials and the climate play the main role in the formation of this case of reddish soil and we could consider it one of the northernmost derivation of Mediterranean inland influence in the Balkan Peninsula.

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