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Comparative mineralogical characteristics of red soils from South Bulgaria

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Abstract

The present study aims to compare mineralogical composition of red soils, formed on marbles in South Bulgaria. We used mineralogical analysis of heavy and light mineral fraction in immersion under polarizing microscope and X-ray diffraction analysis of bulk sample and clay fraction. Three test polygons, located in South Bulgaria were examined: Petrovo, Nova Lovcha and Dobrostan, which are characterized with different latitude, altitude, and exposition. Three or more sites from each polygon were sampled and analyzed. The red soils are formed on white and gray calcite and calcite-dolomite marbles, impure silicate-rich marbles and only in one site – on marble breccias. We determined the following mineral phases in red soils: calcite, dolomite, quarts, and feldspars, mica, illite-type mica, illite, smectite, vermiculite-smectite, and kaolinite. Heavy minerals are represented by amphibole, titanite and epidote, and minor amounts of zircon, garnet, tourmaline, rutile, pyroxene, andalusite, kyanite, sillimanite and apatite. Opaque minerals are predominantly goethite and hematite. Plant tissue is abundant in light fraction from the uppermost soil horizons. Analyses of heavy mineral fraction show presence of metamorphic and igneous minerals which indicate participation of weathering products from other rock types in the nearby area. The types of heavy minerals in soils depend more on composition of parent rocks and geomorphic position than on climate type. Soils from Nova Lovcha show similar composition, but the quantity of goethite and hematite significantly increase in soil from plain. Typical high-metamorphic minerals as andalusite, kyanite and sillimanite present only in Nova Lovcha, while garnet dominates in Petrovo and opaque minerals - in Dobrostan. Red soils, formed on slopes, where erosion prevails over accumulation, contain more illite, smectite and vermiculite-smectite, and very few or no kaolinite, whereas the kaolinite is dominant in soils formed on plain. The mineralogical composition of clays in different polygons depends on geomorphic position (altitude, slope or plain), and less on climate type. The weathering processes in the highest polygon Dobrostan (more than 1200 m) are in early stage (illite, vermiculite-smectite, and smectite), whereas in Nova Lovcha (above 700-900 m) and Petrovo (1000 m) the domination of kaolinite suggests an advanced weathering processes.

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Introduction

A significant part of the area of South Bulgaria is occupied of mountain terrains/high lands, which are built up of different rock types but dominated by meta-carbonate rocks (marbles). The most characteristic types of red soils over carbonate rocks are Terra Rossa, Chromic Cambisols, Rendzic Leptosols, Rhodic Nitisols NTr, etc. (Ninov, 2002). These red soils represent the only soil resource in the region. Previous researchers paid the main attention to the characteristics of marbles from geological point of view. Soil studies there

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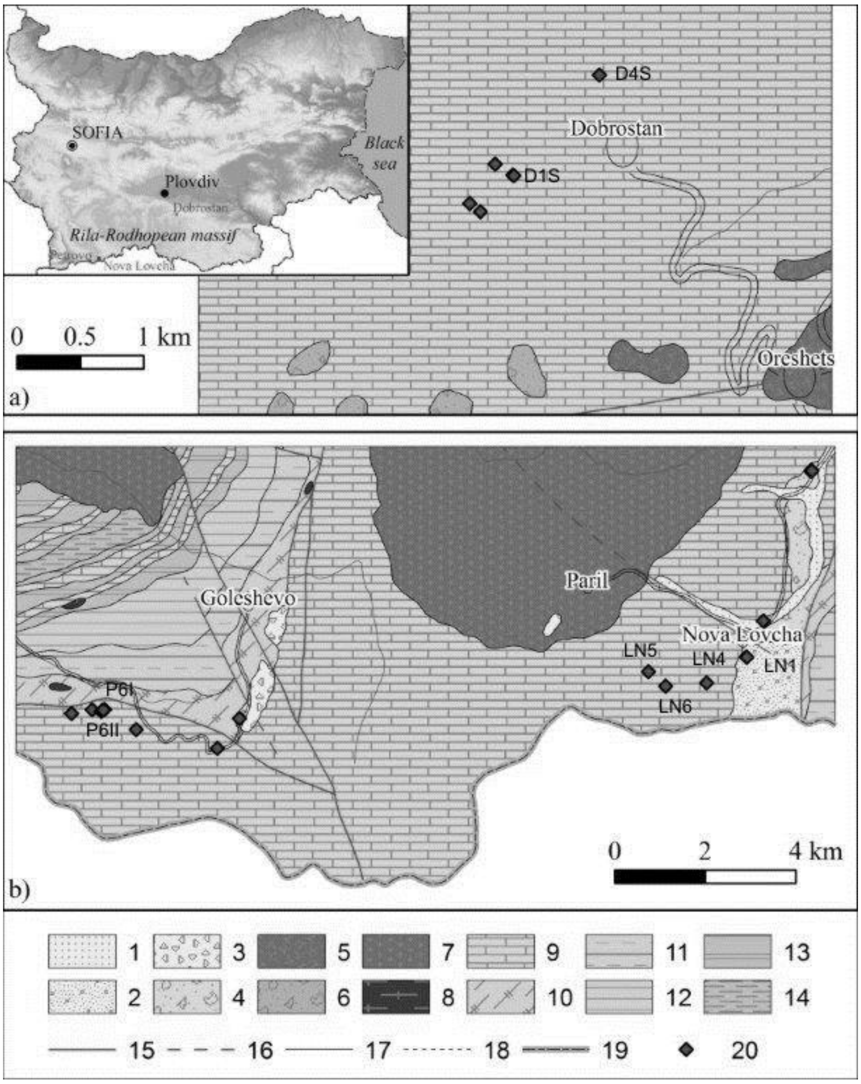
were carried out 38 years ago and were focused on the soil characteristics (Achkov, 1976; Iliev, 1977) – the percent participation of physical clay and humus in the plough zone, values of structural and acid coefficients, and depth of the profile, humic horizon and ground water. The present study aims to compare mineralogical composition of red soils, formed on marbles in South Bulgaria, from three different test polygons..

Material and Methods

The studied region is located in South and South-Western Bulgaria in the area of the mountains Rhodope, Pirin and Slavyanka. We studied soils and weathering crusts on marbles, collected from three test polygons – Petrovo (near the village of Goleshevo), Nova Lovcha, and Dobrostan which are characterized by different latitude, altitude, exposition (Figure 1), and climate conditions. The relief of the three polygons is mountainous with altitude ranging from 700 m (Petrovo and Nova Lovcha) to 1400 m (Dobrostan). Climate conditions vary too: in Dobrostan climate is mountainous, whereas in Petrovo and Nova Lovcha – sub-mountainous with strong Mediterranean influence. The average air temperature in Dobrostan area for the period of 40 years is 7.3°C; rainfall is 823 mm; and humidity - 76% (Kljuchkova, 1979, 1983; Koleva and Peneva, 1990). For the last 80 years in the area of Nova Lovcha the average values are as follows: air temperature – 11.3°C, rainfall – 633 mm, and humidity – 72%; and for Petrovo: air temperature – 14°C, rainfall – 533 mm, and humidity – 66% (Kljuchkova, 1979, 1983; Koleva and Peneva, 1990). Petrovo and Dobrostan are with northern, and Nova Lovcha is with eastern exposure.



Legend:
1) Alluvial deposits (sands and pebbles);
2) Alluvial-proluvial deposits (pebbles);
3) Diluvia deposits (marble breccia);
4) Nevrokop Formation (breccia-conglomerates, conglomerates, sandstones);
5) Dyke complex (rhyolites, trachyryolites, trachydacites);
6) Coal-sandstone formation (conglomerates, sandstones, clays, siltstones, limestones);
7) Upper Cretaceous intrusive complex – Goleshevo, Teshovo and Lehovo intrusives (fine to medium grained biotite and amphibole-biotite granites); *8-14 Rhodope Supergroup*:
8) Metaultrabasites (Metasepentenites);
9) Asenovgrad Group – Dobrostan Formation (massive and layered marbles); *10-12 Sitovo Group:*
10) Lukovo gneiss-schist Formation (biotite and two mica gneisses, gneiss-schists, schists, marbles, amphibolytes);
11) Bachkovo leptinite Formation (muscovite and two mica leptinites and leptinite gneisses);
12) Boikovo gneiss Formation (biotite and two mica gneisses); *13-14 Rupchoska Group:*
13) Vacha Variegated Formation (amphibole-biotite, biotite and two mica gneisses, gneiss-schists, schists, marbles, amphybolites);
14) Bogutevo plagio-gneiss Formation (migmatized plagioclase gneisses); *15-16 Fault*
15) established ;
16) inferred; *17-18 Geological boundary*
17) lithological;
18) transgressive;
19) National boundary;
20) Observation points.

Figure 1. Geological maps of the studied areas: a) Dobrostan; b) Petrovo and Nova Lovcha (after Kozhoukharov and Marinova, 1991; Kozhoukharov et al., 1991).

Parent rocks are marbles referred to Dobrostan Formation (Kozhouharov, 1984) in the three polygons. In the area of Nova Lovcha marble breccias from Paril Formation (Zagorchev, 1995) are also presented. The breccias are composed of angular and sub-angular marble pieces from Dobrostan Formation in clayey-carbonate matrix. The red soils are formed on white and gray calcite and calcite-dolomite marbles, impure silicate-rich marbles and only in one site – on marble breccias. Soils formed on these marbles have been described as Chromic Cambisols and Rendzic Leptosols (Ninov, 2002).

Sampling includes soils from the three polygons (Figure 1). In polygon Dobrostan we sample 2 profiles: D1S formed on the slope and with thickness of 50 cm, and D4S, 80 cm thick and formed on the accumulative plane. In Petrovo we sample 2 profiles located on the hill-slope in close proximity and formed on two marble types – Profile P6I is formed on white marbles, whereas P6II is formed on impure silicate-rich marbles. The thickness of the profiles is 20-40 cm. Four profiles are sampled in polygon Nova Lovcha. On the hill-slope the thickness is 5-40 cm (profiles LN 5 and LN6), and in the accumulative plane it is up to 200 cm (LN1 and LN4). Profile NL5 is formed on marble breccias. In all profiles a distinct weathered crust is observed, but soil horizons are not clearly defined in the three polygons.

Samples from soils are submitted to mineralogical analyses. Grain-size fraction between 63 and 125 microns is divided to light and heavy fraction by Bromoform (CHBr3 - 2,93 g/cm^3). Fractions are studied in immersion Eugenol (refractive index n_e=1.541) under polarizing microscope. Quantitative evaluations are made on the basis of minimum 400 grains of the light fraction and 500 transparent grains of the heavy fraction. Mineral compositions of bulk samples and fractions less than 0.063 mm and clay fractions less than 0.002 mm are identified by X-ray powder diffraction analysis (XRD) using TUR M62 Diffractometer, Co filtered irradiation.

Results and Discussion

The composition of light mineral fraction in all samples is as follows (Figure 2): dominant mineral is quartz, followed by plagioclase and potassium feldspar. A significant presence of calcite or dolomite grains is registered too. The content of plant tissues and pollen grains is abundant.

The composition of the light mineral fraction is very similar in soils from Petrovo and Nova Lovcha. The amount of quartz is almost equal, but the feldspars and micas are nearly twice more in soils from Petrovo. Carbonate minerals are very weakly preserved in polygon Petrovo (about 1-6%). In Nova Lovcha an abundant carbonate presence is registered (36-42%), represented by calcite and dolomite grains, except for sample NL4. Plant tissues and pollen grains represent about 7-8% of the light fraction in both polygons. In polygon Dobrostan, a clear difference between composition of soils on hill-slopes and accumulative plain is observed. On hill-slopes quartz and plagioclases are in almost equal quantities, whereas in accumulative plain quartz is the dominant mineral. Calcite grains prevail in the light fraction from slope (54%), and they are present by 13% in the plain. The plant tissues follow the same trend.

Heavy minerals are represented by amphibole, titanite and epidote, and minor amounts of zircon, garnet, tourmaline, rutile, pyroxene, andalusite, kyanite, sillimanite and apatite (Figure 3). Opaque minerals are predominantly goethite and hematite.

Analyses of heavy mineral fraction show presence of metamorphic and igneous minerals which indicate participation of weathering products from other rock types than marbles in the nearby source area. According to the geological map of Bulgaria (Kozhoukharov and Marinova, 1991; Kozhoukharov et al., 1991) granites referred to Upper and Precambrian schists, gneisses and amphibolites crop out in the nearest source areas. Also, sediments from the Neogene aged Nevrokop Formation contain an abundance of heavy minerals yielded from metamorphic and igneous rocks. The types of heavy minerals in soils depend more on composition of parent rocks and geomorphic position than on climate type. Soils from Nova Lovcha show similar composition, but the quantity of goethite and hematite significantly increase in soil from plain. Typical high-metamorphic minerals as andalusite, kyanite and sillimanite present only in Nova Lovcha, while garnet dominates in Petrovo and opaque minerals - in Dobrostan.

After X-ray diffraction analyses we determined the following mineral phases in red soils: calcite, dolomite, quarts, and feldspars, mica, illite-type mica, illite, smectite, vermiculite-smectite, and kaolinite. Red soils, formed on slopes, where erosion prevails over accumulation, contain more illite, smectite and vermiculite-smectite, and very few or no kaolinite, whereas the kaolinite is dominant in soils formed on plain.

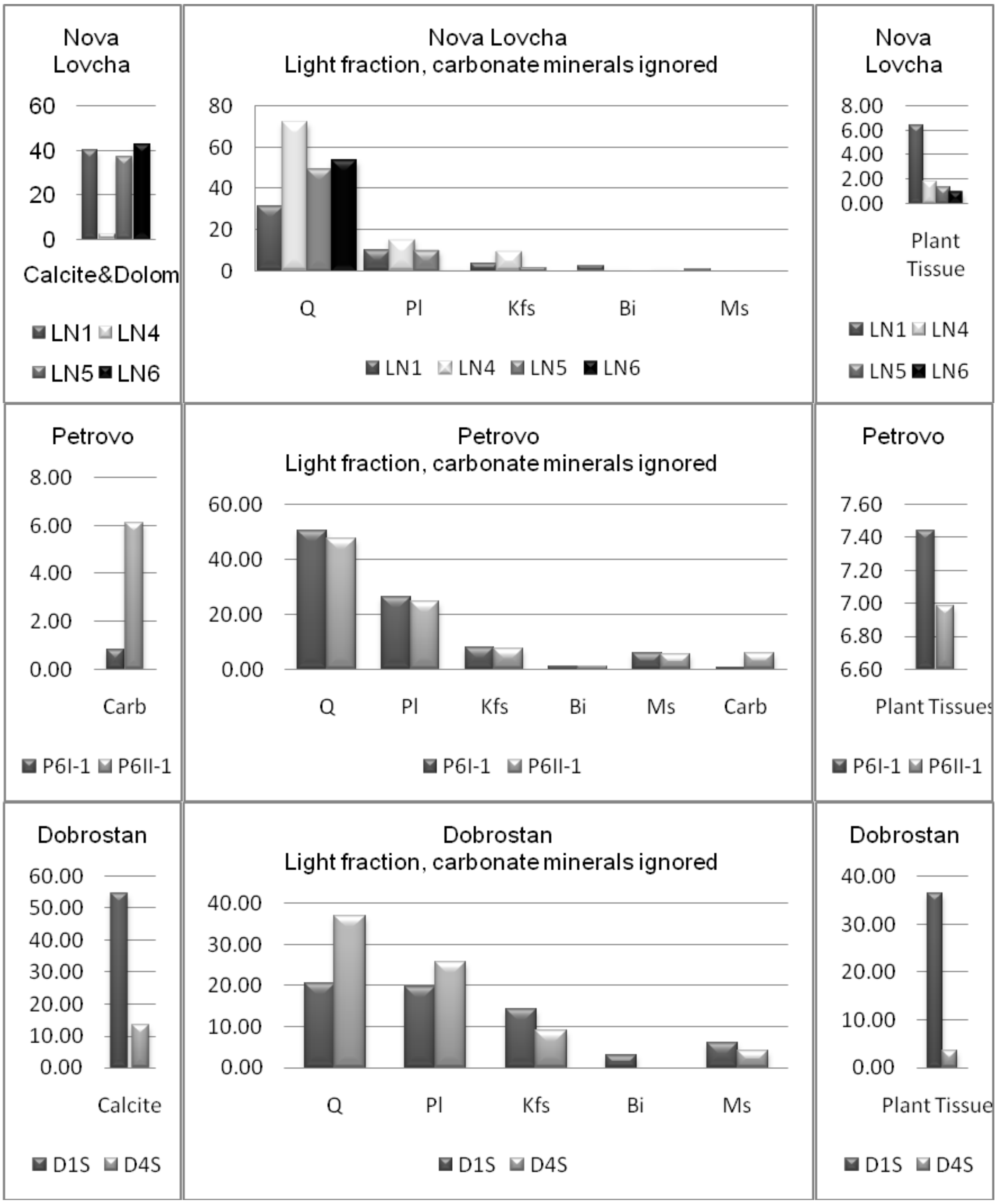


Figure 2. Mineral composition of the light fraction (0.063-0.125 mm)

In the case of profiles on the slopes, the powder diffraction patterns of samples taken from the materials placed over all types of marble (calcite - Nova Lovcha, Dobrostan, Petrovo, dolomite - Nova Lovcha and silicate-containing - Petrovo) show presence of calcite, quartz, feldspars and various clay minerals (Figure 4).

In any case, a vertical distribution of different minerals (bottom-up) is observed: a decrease of the amount of the carbonate component and an increase of the clay minerals. The presence of terrigenous minerals in the soil near New Lovcha most likely due to the import of the material from the nearby Neogene sediments of Nevrokop Formation, while the presence of terrigenous material in red soils in Dobrostan comes from the weathering products of the adjacent volcanic rocks. In all studied red soils crystalline iron oxides and oxy-hydroxide minerals - hematite (Hem) and goethite (Geoh) are presented.

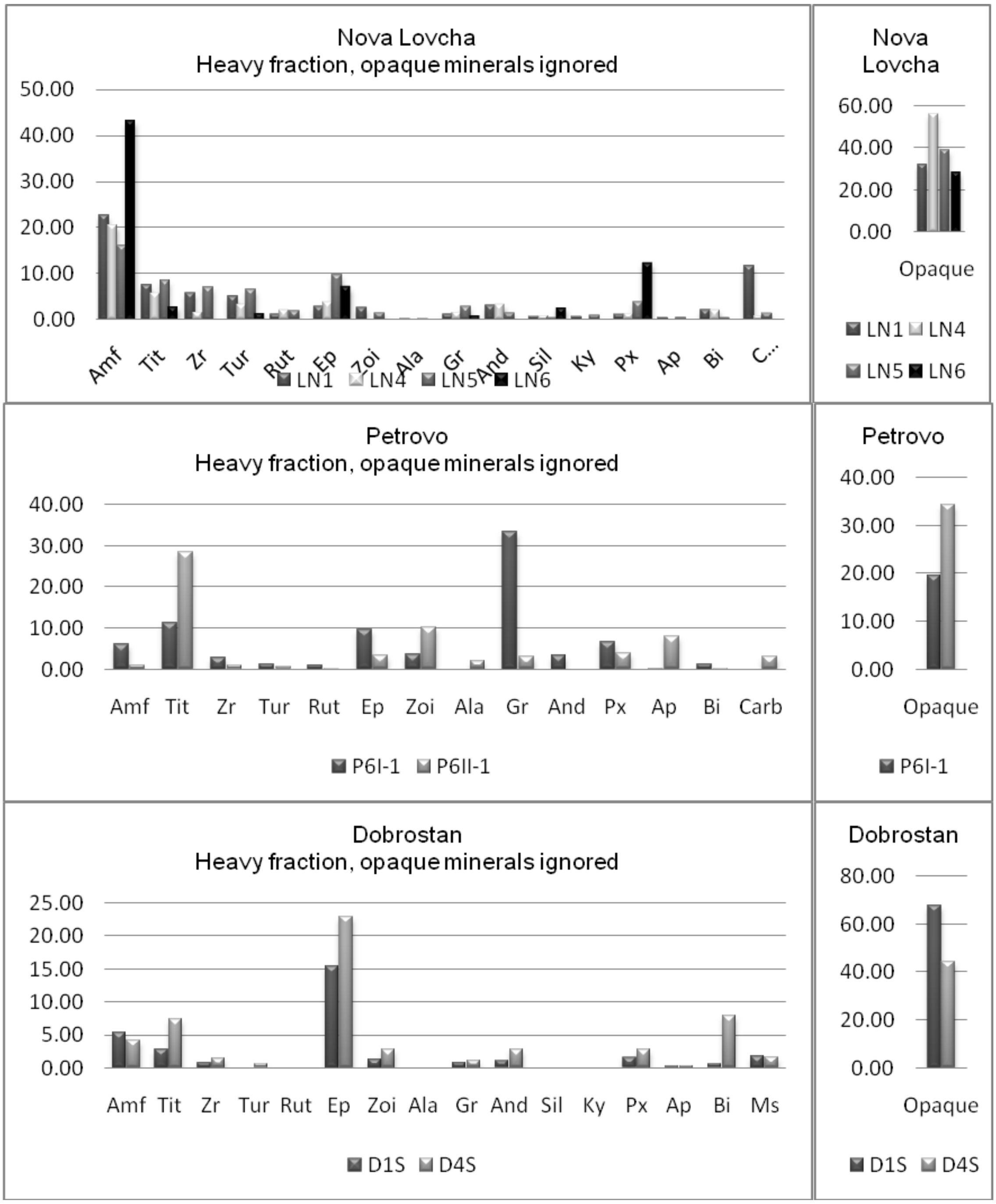


Figure 3. Mineral composition of the heavy fraction (0.063-0.125 mm).

The powder diffraction patterns of samples formed on the plain in polygons Nova Lovcha (LN1) and Dobrostan (D4S) do not show any vertical zoning. The phase composition of the clay fraction (<0,002 mm) of the soil developed over all types of parent marble rocks shows that in Nova Lovcha and Petrovo areas soil is presented predominately by kaolinite (Figure 5a), whereas in the region of Dobrostan the clay fraction is composed of vermiculite-smectite type minerals (Figure 5b). This result suggests that in areas with an influence of the Mediterranean climate as Petrovo and Nova Lovcha, weathering is more advanced compared to the Dobrostan area, which is characterized by mountain climate.

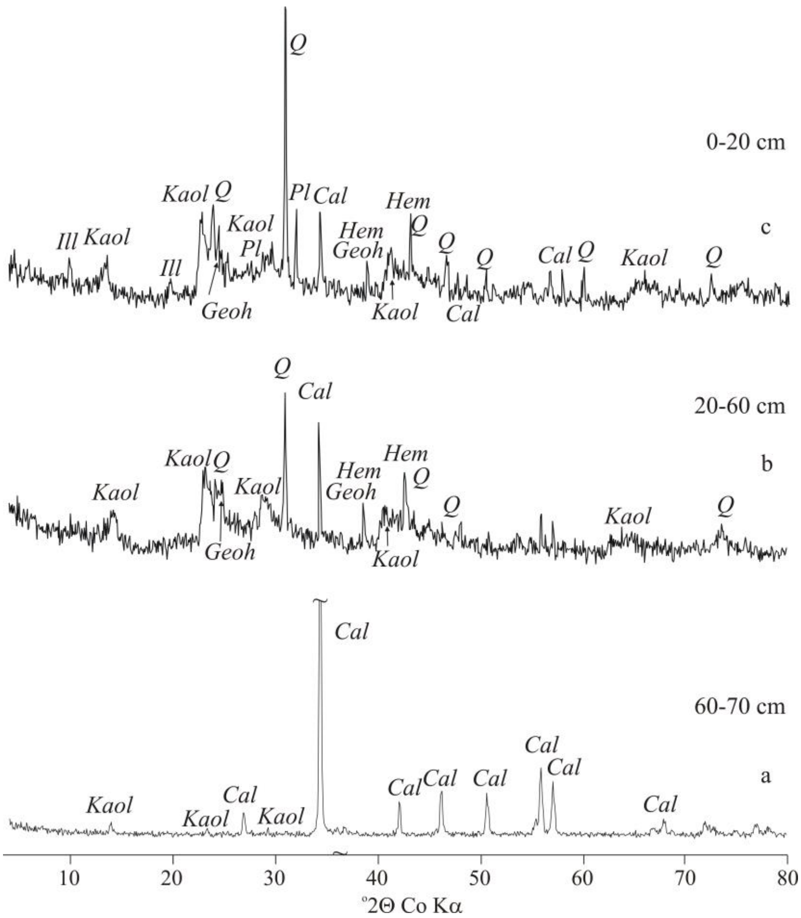


Figure 4. Powder x-ray diffraction patterns of soil samples developed over the white calcite marbles in polygon New Lovcha – LN5

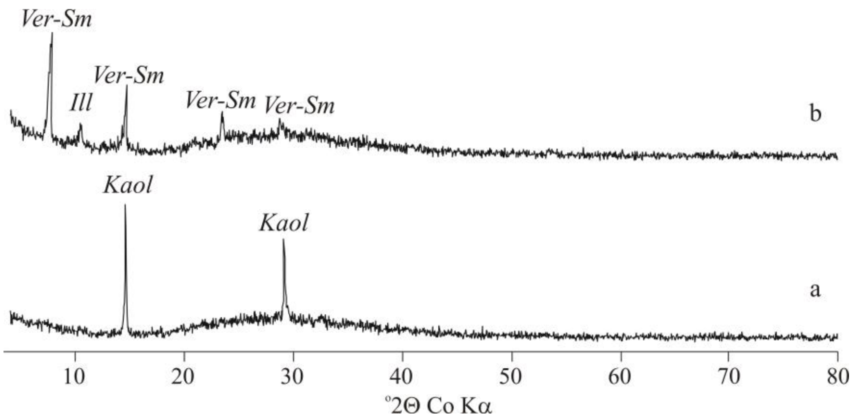


Figure 5. Powder x-ray diffraction patterns of clay fractions < 2m: a) Petrovo, Nova Lovcha; b) Dobrostan

Conclusion

The geomorphic position and climate are the main controlling factors for the clay mineralogy The mineralogical composition of clays in different polygons depends on the altitude, position on the slope or plain, and on climate type – mountainous or sub-mountainous with Mediterranean influence. The weathering processes in the highest polygon Dobrostan (more than 1200 m) are in early stage (illite, vermiculite-smectite, and smectite), whereas in Nova Lovcha (above 700-900 m) and Petrovo (1000 m) the domination of kaolinite suggests an advanced weathering processes. The composition of the parent rocks and other rocks outcropping in the nearest source area play the most important role for the heavy mineral composition of soils.

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