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Original scientific paper

FORMATION CONDITIONS, GENESIS, EVOLUTION, CLASSIFICATION AND SOME FEATURES OF SOILS FORMED ON GYPSUM ROCKS IN THE REPUBLIC OF MACEDONIA

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The current paper studies the formation conditions, genesis, evolution, classification, morphological features, mechanical composition and chemical properties of soils formed on gypsum rocks in the Republic of Macedonia. The soils have been formed on mountain relief with steep slopes upon gypsum and anhydrite. Warm continental climate with inconsiderable impact of the Mediterranean climate prevails in the area. The soils occur underneath hill pastures, which are rather poor from a floristic point of view and they are characterized by minor canopy closure. Destruction of the natural forest vegetation and intensive grazing on the hill pastures that have remained following the destruction thereof have caused heavy soil erosion. Our research has ascertained that gypsic rendzic leptosol and gypsic pararendzina have been formed on gypsum rocks. Both soil types are distinguished by a light mechanical composition dominated by physical sand. Carbonates are present in both soil types in all soil assays while in certain soil assays the gypsum has been fully washed.

Key words: formation conditions; genesis; evolution; classification; gypsum rocks; gypsic pararendzina; gypsic rendzic leptosol

INTRODUCTION

Soils upon gypsum rocks in our country have not been studied yet; hence, there is not any data available from field and laboratory research. The aim of the current research is to provide initial data on the aforesaid soils in our country and wider in the Balkan Peninsula. We have observed the natural conditions of their formation, their genesis, evolution, classification along with their physical and chemical properties, with particular emphasis on the exchangeable ions composition and humus composition. Only a portion of the yielded results have been rendered here.

The current study is a part of a project within the framework of the MASA programme, which has funded the study. Field research and laboratory analyses have been conducted in line with the known methods [1–5].

Soils on gypsum rocks do not bear great significance for our agriculture and forestry given that they are underneath poor pastures. Due to their small-range distribution and specific features, in a number of countries these soils are specially protected and listed in the red book of natural rarities.

In former Yugoslavia, their presence was referred to in 1963, when they became part of the first version of soil classification as gypsic pararendzina [6]. In the subsequent versions of this classification they were eradicated due to their scarce distribution. In our literature, there is data that gypsic pararendzina have been formed upon gypsum rocks above the Radika River valley [7]. A definition of gypsic horizon [8] has also been provided, which used to be defined as gypsum [9], whereas the taxonomic unit containing gypsic horizon was labeled as gypsic [8]. Gypsic soil material was defined in our regosols [8]. Information on research into soils on gypsum rocks have been published in foreign literature [10–15].

RESEARCH RESULTS

In the vicinity of the villages of Dolno and Gorno Kosovrasti (Debar area), 7 soil profiles on gypsum rocks (Map 1) were excavated, studied and morphologically described, whereof four profiles were gypsic rendzic leptosol with A-R profile and three profiles were gypsic pararendzina with A-AC-C profile.

In the field, we observed the soil-forming factors determining the formation of these soils, their evolution, morphology and classification.

Map 1. Profile location

Soil-Forming Factors

Geographic position and relief

The relief characteristics of gypsum from Kosovrasti have been described before [16–18]. Those papers underscore the considerable solubility of gypsum $CaSO_4 \times 2H_2O$ and anhydrite $CaSO_4$, which results in subaerial erosion and pile-up forms in the relief similar to karst forms in limestone areas. Gypsum karren are such forms – vertical fractures through which water passes thereby dissolving the rock and creating fissures and diastromes. These soils are formed on mountain relief, distinguished by steep slopes, which is the reason why a larger section of the gypsic soils are eroded, the bare rock remaining on the surface. The small areas where these soils were found are characterized by mosaic microrelief. It comprises micro-indentations and micro-elevations. Soils occur in the micro-indentations.

Parent material

The rocks where the gypsic soils were formed have been geologically mapped on a scale of 1:25.000. In the geological map 1:100.000 [19], gypsic forms have been presented as gypsum and anhydrite. Anhydrite occurs in the inner section of the gypsic mass, where it gradually turns into alabaster. Organic matter, limestone fragments, hornstone mass and virgin sulphur are often found in the gypsic mass. In the field, we established that gypsum rocks contained $CaCO_3$ and silica residuum.

During field research, we took gypsum rock fragments from the excavated profiles (Table 1).

Table 1. Content of $CaSO_4$ and $CaCO_3$ in gypsum rocks from the studied profiles

Number of profile	$CaCO_3$ %	$CaSO_4 \times 2H_2O$ %
1 and 2	2.02	95.43
3	1.54	96.38
5	5.12	89.77
6	4.04	93.15
7	2.36	95.33

Climate

The data about Debar [20], which is in close proximity to the area of concern, will be utilized for climate description. Warm continental climate prevails in the area, coupled by minor impact of the Mediterranean climate coming from the Adriatic Sea, which is felt along the Radika River, where the profiles were excavated. The said impact is more intensely reflected on the pluviometric regime rather than on the heat regime. The average annual temperature in Debar is 11.8 °C. The lowest average monthly temperature in January is 0.7 °C, and the highest in July is 22.2 °C, with an amplitude of 21.5 °C. The absolute monthly maximum was measured in July, which is 38 °C, and the absolute monthly minimum in January –23.9 °C. The sum of temperatures in the vegetation period (above 10 °C) amounts to 3.627 °C. The total annual precipitation equals 890 mm. Most of the rainfall occurs in autumn and wintertime. December is the rainiest month of all with 120.8, then follows November with 115.2, October with 85.8, January with 84.2 and February with 81.6 mm. July is the most arid month with 33.9 mm. This timetable of precipitation is distinctive of the Mediterranean pluviometric regime. The annual drought index according to De Martone totals 40.8 whereas the annual precipitation factor according to Lang amounts to 75.4. Consistent with the latter, the climate is semi-humid while based on the heat indicator, the climate is moderately warm. In the course of the year, the moist and the arid periods give way to each other.

Such climate conditions accompanied by other soil-forming factors have an influence on the soil processes. The significant precipitation intensity and the frequent occurrence of downpours triggers erosion. The relatively high precipitation brings about washing of gypsum and $CaCO_3$ (degypsization and decarbonatization). The relatively high temperature is a reason for stronger mineralization of organic residues. Mull humus is formed in the soil and biogenic elements are produced.

Vegetation

These soils are distributed underneath hill pastures. Hill pastures are secondary vegetation formations derived from gradual and long-term degradation of the once widely distributed forest phytocenoses.

Hill pastures developing on gypsum on the territory of the Republic of Macedonia are still considered as a vegetation type that has not been studied sufficiently from a syntaxonomic aspect.

The field research into soils proceeded simultaneously with the vegetation research. The team included a phytocenologist – Academician V. Matevski. He studied the vegetation of the soils on gypsum rocks in the region of the village of Dolno Kosovrasti village. He made 8 vegetation records and described the plant communities in line with the commonly accepted methodology [21]. These communities develop at an altitude ranging between 625 and 735m. Hill pastures on soils upon gypsum rocks comprise a single plant community only: *Thymus ciliatopubescens* var. *poliothrix – Silene speguliifolia* subsp. *soskae* comm. The quoted community is of limited distribution and rather scarce from a floristic perspective. It does not occur on any other locality in the Republic of Macedonia. It belongs to the class *Festuco-Brometea* Br. Bl. et Tx. 1943, order *Astragalo-Potentilletalia* Micevski 1970 and the alliance *Saturejo-Thymion* Micevski 1970 [22].

The vegetation does not cover the soil surface in its entirety. The canopy closure totals 60–85%. The grass vegetation share in the biological accumulation of mature humus is with a narrow ratio of C : N. The humus is loaded with Ca-salts of humic acids and argillohumins, and it contributes to the creation of a fine granular structure. Its mineralization prompts a pile-up of biogenic elements.

Time impact

The duration of soil-forming processes is pivotal for the soil alterations generated by the processes thereof. In our circumstances, washing of easily-soluble matter and accumulation of organic matter take least time; therefore it is those processes that happen first [23]. Washing of $CaCO_3$ and $MgCO_3$ is slower provided they are present in the parent material. Given that time-consuming processes (clay formation, clay washing) do not occur in these soils, one may deduce that the soils are young from a temporal perspective as well as evolutionally young since they solely contain hor.A and C (or A and R) without hor. (B) or Bt, for whose formation a longer period of time is required.

Anthropogenic factor

The human activities have engendered large-scale modifications of the ecosystems and soils. The destruction of natural forest vegetation and the intensive grazing on the hill pastures that have remained after the destruction have caused heavy soil erosion. Sizable areas are now deprived of soils, and biological accumulation of organic matter and biogenic elements has diminished.

The enclosed Table 2 renders a number of soil-forming factors and the external soil morphology.

Table 2. Some soil-forming factors of soils formed on gypsum rocks in the Republic of Macedonia

Profile No	Parent material	Altitude m	Exposure	Inclination %	Stoniness %	Occurrence of outcrops %	Plant community
1	gypsum/anhydrite	735	southern	0–3	15–35	15–50	*Thymus ciliatopubescens* var. *poliothrix* – *Silene spegulifolia* subsp. *soskae* comm.
2	gypsum/anhydrite	735	southern	0–3	15–35	15–50	
3	gypsum/anhydrite	725	southern	>45	35–60	0.1–3	
5	gypsum/anhydrite	700	southeastern	>45	15–35	15–50	
6	gypsum/anhydrite	690	southeastern	>45	15–35	15–50	
7	gypsum/anhydrite	800	southeastern	>45	15–35	15–50	
8	gypsum/anhydrite	740	southeastern	>45	15–35	15–50	

Genesis, Evolution, Classification and Morphology

Genesis and evolution

The soil-forming processes in these soils depend on the elaborated array of soil-forming factors, whereof the following are worth underpinning: presence of rock rich in gypsum, $CaCO_3$ and silica residuum; then, presence of grass vegetation that is not heavy; rather substantial precipitation and relatively high temperature attributable to the low altitude. These conditions are different from those where rendzina on hard limestone and dolomites are formed (compact pure limestone, negligible residual remnants, absence of gypsum, high altitude, heavy grass vegetation, low temperature, greater precipitation).

The following processes take place within gypsic rendzic leptosol: (1) physical decay of rock, normally to the depth of the humus horizon; (2) gypsum dissolution and washing (degypsization); (3) dissolution and washing of $CaCO_3$ and $MgCO_3$ (decarbonatization, decalcification), and (4) pile-up of organic matter and formation of humus horizon.

The physical decay is of diverse intensity and it may be determined by the presence of skeleton particles in hor. A (up to 40%). It does not usually occur in rendzina on hard limestone and dolomites where only decarbonatization happens; therefore, skeleton particles are rarely found in them in hor. A. In addition, gypsum rocks are softer than limestone and more prone to physical decay resulting in regolith for formation of hor. A.

In contrast to $CaCO_3$, gypsum is much more soluble (20 parts anhydrite and 25 parts gypsum in 10.000 parts water), and solely water is essential for its dissolution. The dissolution of $CaCO_3$ necessitates the production of H_2CO_3 in the soil, which is the reason why its dissolution and washing are both much slower. Therefore, gypsum content in the profile rapidly plummets and the content of silica residuum increases (in %). Thus, water retention augments and plant population is facilitated along with the launch of the process of organic matter accumulation. The intensity of gypsum washing depends on the soil-forming duration. It may be washed by hor. A entirely, as in the case of two of the four studied profiles of gypsic rendzic leptosol.

The washing of $CaCO_3$ occurs at a later stage, together with accumulation of organic matter and its mineralization resulting in formation of H_2CO_3, which dissolves $CaCO_3$ yielding $Ca(HCO_3)_2$. The process is much more protracted; hence, the solum comprises much more $CaCO_3$ than $CaSO_4$.

With all of the aforementioned processes, soil genesis proceeds concurrently with regolith formation and relative enrichment with silica residuum. This facilitates plant population and emergence of the next process, i.e. accumulation of organic matter and its humification and mineralization with pile-up of biogenic elements. The solid rock is first inhabited by lichens and mosses. Regolith deepening allows for creation of prerequisites for inhabiting by grass and forest vegetation and by fauna representatives. The soil is enriched with humifying organic residue. The resulting humic acids bond with Ca and the clay of silica residuum. Thus, humus is formed, constituted of Ca-humates and argillohumins (1.6–6.3% humus in hor. A). Mineral acids (H_2CO_3) are also neutralized by bonding with $CaCO_3$, so there is not any soil acidification whatsoever (pH of water from 7.4 to 7.6). Accumulation of mull humus facilitates engendering of stable fine granular structure.

From this elucidation it becomes evident that gypsic leptosol is a prior stadium of gypsic rendzic leptosol, and that regolith formation proceeds simultaneously with soil genesis.

The processes of rendzina formation are herein marked as rendzinization [7]. These processes also develop in our gypsic pararendzina, the difference being that $CaSO_4$ washing also takes place in the latter and that gypsic regosol occurs as a previous stage. Contrary to gypsic rendzic leptosol, regolith formation does not proceed concurrently with soil genesis because it has been completed earlier during the formation of gypsic regosol. The genesis of gypsic pararendzina is distinguished by the following processes: (1) gypsum dissolution and washing (degypsization), thereby conducting its redistribution in the solum; (2) $CaCO_3$ and $MgCO_3$ dissolution and washing (decarbonatization, decalcification) initiated in the preceding stage of gypsic regosol; (3) melanization and mineralization of organic matter and establishment of a dark ("melanos") humus horizon and enrichment with biogenic elements.

Gypsum washing is done faster and more intensely owing to its greater solubility compared to $CaCO_3$, resulting in a big difference in its content between horizons A and AC. In one of its profiles hor. A is wholly degypsized.

$CaCO_3$ washing is enabled via mineralization of organic residues, which yields H_2CO_3. The process is lengthier, it is more time-consuming. $CaCO_3$ is washed only partially and the soil remains calcareous. This averts the evolution of these soils into the subsequent A-(B)-C stage.

The melanisation process, under the influence of grass vegetation, produces humic acids, which bond with Ca ions and secondary minerals from silica residuum (illite), thereby yielding Ca salts of huminic acids and humic-clay complexes (argillo-humins). Mollic horizon and a stable granular structure are formed with the aforementioned process. Humification is accompanied by mineralization of organic residues from the easily-decomposable part of the humus, resulting in nutrients.

Rendzinization creates differences between gypsic regosol and gypsic pararendzina: a humus accumulative hor. A is formed, abundant in humus, darker, with more distinct structure, richer in biogenic elements, more fertile. Rendzinization does not alter the mechanical composition; there is neither clay formation nor clay transportation.

Gypsic rendzic leptosol and gypsic pararendzina as young soils loaded with $CaCO_3$ do not evolve into the next stage by hor. (B) formation, as it is the case with some other rendzina formed on friable calcareous rocks.

Classification

The latest classification of soils in the Republic of Macedonia [8] does not include again soils formed upon gypsum in view of the fact that they occupy minor areas. If the principles underlying the quoted classification are applied, it could be supplemented by the subtype gypsic pararendzina, which would fall into the type rendzina in the great soil group of mollisols. This subtype would comprise the variety on gypsum rocks and the form based on texture.

Pertaining to gypsic rendzic leptosol, from classification perspective, they are the closest ones to rendzina on hard limestone and dolomites but they are different from them given that they are formed on another parent material; they contain gypsum, carbonates and skeleton particles in the solum. Consequently, they might be separated as an independent type of gypsic rendzic leptosol in the great soil group of mollisols.

According to the criteria of World *reference base for soil resources* 2014 [24], gypsic rendzic leptosol would fit in the referential soil groups of leptosols, while gypsic pararendzina would belong to regosols. We have attempted to classify the studied soils in compliance with the aforesaid classification. On the basis of this classification, prof. 1, 3 and 5 will be classified as Humic-Calcaric-Leptosol, prof. 8 as Gypsiric-Calcaric-Leptosol, prof. 2 as Leptic-Calcaric-Regosol and prof. 6 and 7 as Gypsiric-Calcaric-Regosol.

Morphology

By their external morphology, gypsic rendzic leptosol and gypsic pararendzina are similar to rendzina on hard limestone and dolomites. They cover only a single section of the gypsum rock surface, in the depressions. The microrelief resembles a mosaic, and it features micro-depressions and micro-elevations that give way to each other at a small distance. Vegetation does not cover the surface soil in its entirety.

Gypsic rendzic leptosol sets itself apart with a profile shallower than gypsic pararendzina. The observed gypsic rendzic leptosol possesses a mollic horizon, lithic properties, calcareous soil material, and one profile contains gypsic soil material, too. The mollic horizon in the studied gypsic rendzic leptosol is 16-21cm in depth. Horizon A exhibits intense variation in depth at a small distance due to the uneven ground. Gypsic rendzic leptosol has a profile of the A-R type. The colour of the mollic horizon has been identified according to Munsell colour system in dry and moist condition (Table 3). In dry condition, the soil is gray-brown or dark gray-brown or light brown. Mollic horizon is friable, loose; it is non-coherent and easy to dig. The skeleton is always present to a lesser or higher extent.

Table 3. Soil colour, according to Munsell colour system

No of profile	Horizon and depth (cm)	Colour in dry condition	Colour in moist condition
Gypsic rendzic leptosol			
1	A 0–18	10YR 4/2 dark grayish-brown	10YR 3/2 very dark grayish-brown
3	(A) 0–16	10YR 5/2 grayish-brown	10YR 3/2 very dark grayish-brown
5	A 0–21	10YR 5/2 grayish-brown	10YR 3/2 very dark grayish-brown
8	(A) 0–17	10 YR 6/2 light brownish-gray	10YR 4/2 dark grayish-brown
Gypsic pararendzina			
2	A 0–19	10YR 4/2 dark grayish-brown	10YR 3/2 very dark grayish-brown
2	AC 19–32	10YR 6/2 light brownish-gray	10YR 4/2 dark grayish-brown
6	A 0–15	10YR 5/2 grayish-brown	10YR 3/2 very dark grayish-brown
6	AC 15–24	5Y 7/2 light gray	2.5Y 5/2 grayish-brown
6	C1 24–50	2.5Y 8/2 white	2.5Y6/2 light brownish-gray
6	C2 50–80	2.5Y 8/0 white	2,5Y 7/2 light gray
7	A 0–15	10YR 5/2 grayish-brown	10YR 3/2 very dark grayish-brown
7	AC 15–28	10 YR 7/1 light gray	10YR 6/2 light brownish-gray
7	C 28–43	10 YR 8/1 white	10YR 6/2 light brownish-gray

In contrast to rendzina on hard limestone and dolomites, it is scarcely overgrown with grass vegetation roots, and it is less humic. In a number of profiles, gypsum is washed by solum but carbonates are present in all profiles. In certain profiles, the reaction to $BaCl_2$ is weak while in some profiles white deposit occurs. Horizon A sharply passes through the solid rock, and in one profile the solid rock is physically decayed.

We have selected prof. 5 as a profile typical of gypsic rendzic leptosol, distinguished by the following morphological properties: A 0–21 mollic horizon with gray-brown colour in dry condition and a very dark gray-brown in moist condition; humic, calcareous, arid, friable, easy to dig, skeletal, permeated by scarce grass vegetation roots. Its structure is granular, very fine to fine, and distinctive. The addition of $BaCl_2$ results in emergence of white deposit. It harshly penetrates the solid rock via a sub-horizon of physically decayed gypsum.

The observed gypsic pararendzina have a mollic horizon, leptic properties, calcareous soil material, and in a number of profiles they have gypsic soil material. They possess a A-AC-C-R type of profile. The horizon colour is identified in line with the Munsell colour system (Table 3). The mollic horizon depth ranges between 15 and 19 cm, while the transitional AC horizon depth ranges between 9 and 13 cm. We have established carbonates in all horizons. Gypsum occurs in all horizons bar hor. A of prof. 2. All horizons are arid, friable and easy to dig. We shall elaborate on the morphological properties of the typical profile – prof. 6: A (0–15) mollic horizon with gray-brown colour in dry condition and a very dark gray-brown in moist condition; hugely humic, skeletal, calcareous. The addition of $BaCl_2$ results in a slight white deposit. It is dry, friable, easy to dig, intertwined by rare grass vegetation roots. Its structure is granular, very fine to fine, and distinct.

AC (15–24) transitional horizon with light gray colour in dry condition and a gray-brown colour in moist condition. It is hardly humic, skeletal, dry, friable, without structure, calcareous. A white deposit ensues from the addition of $BaCl_2$. It gradually passes into the C horizon.

C (24–80) parental material, white in colour in dry condition and light brownish-gray in moist condition. It is dry, friable, easy to dig, calcareous. A white deposit ensues from the addition of $BaCl_2$. It harshly penetrates a physically decayed gypsum rock.

LABORATORY RESEARCH RESULTS

Mechanical Composition

The results of the mechanical composition analyses are provided in Table 4.

Judging from the results, a conclusion may be drawn that gypsic rendzic leptosol contains much skeleton (approximately 30–40% skeleton). It is only prof. 8 that comprises little skeleton. As far as fine earth fractions are concerned, fine sand (44–88%) is dominant. There is much lesser presence of silt (17–24%) and coarse sand fractions (13–23%). Clay fraction (3–17%) comes last in this respect.

Table 4. Mechanical composition of soils formed on gypsum rocks in the Republic of Macedonia (in % of fine earth)

No of profile	Horizon and depth (cm)	Skeleton >2 mm	Coarse sand 0.2–2 mm	Fine sand 0.02–0.2 mm	Coarse + fine sand 0.02–2 mm	Silt 0.002–0.02 mm	Clay <0.002 mm	Silt+ clay <0.02 mm	Texture class by Scheffer & Schachtschabel
Gypsic rendzic leptosol									
1	A 0–18	35.98	15.3	44.3	59.6	23.4	17	40.4	sandy clay loam
3	A 0–16	39.31	23.2	35.4	58.6	24.5	16.9	41.4	sandy clay loam
5	A 0–21	29.75	13	67.2	80.2	16.6	3.2	19.8	loamy fine sand
8	A 0–17	3.94	4.1	88.2	92.3	2.1	5.6	7.7	loamy fine sand
Gypsic pararendzina									
2	A 0–19	46.2	14.5	49.7	64.2	19.5	16.3	35.8	sandy clay loam
2	AC 19–32	35.88	9.8	59.4	69.2	17.1	13.7	30.8	fine sandy loam
6	A 0–15	44.79	20.5	56.6	77.1	14.5	8.4	22.9	loamy fine sand
6	AC 15–24	21.92	9.4	78.1	87.5	3.1	9.4	12.5	loamy fine sand
6	C1 24–50	13.18	10	84.4	94.4	0.3	5.3	5.6	loamy fine sand
6	C2 50–80	17.55	9.4	83.6	93	0.3	6.7	7	loamy fine sand
7	A 0–15	21.19	10	80.8	90.8	4.5	4.7	9.2	loamy fine sand
7	AC 15–28	0.51	1.9	84.1	86	2.8	11.2	14	loamy fine sand
7	C 28–43	1.79	1.4	92.1	93.5	0.8	5.7	6.5	loamy fine sand

Physical sand is much more common than physical clay. Taking into consideration that skeleton and physical sand prevail in these soils, it may be construed that physical decay is intense in gypsic rendzic leptosol. Clay content is inversely proportional to the content of $CaCO_3$ + $CaSO_4$. The greater the share of $CaCO_3$ + $CaSO_4$, the lesser the content of silica residuum comprising clay. Thus, for instance, in prof. 1 and 3 the amount of $CaCO_3$ + $CaSO_4$ ranges from 13 to 25% whereas clay constitutes 17%, and in prof. 5 and 8 that amount is around 90% with only 2–3% clay. If mechanical composition of gypsic rendzic leptosol is compared to that of rendzina on hard limestone and dolomites [7], it will be ascertained that gypsic rendzic leptosol includes more skeleton and physical sand and less silt and clay. It testifies to the rather intense physical decay within gypsic rendzic leptosol. Besides, it is likely that non-soluble residuum in gypsic rendzic leptosol comprises coarser particles.

With respect to their mechanical composition, gypsic rendzic leptosol represent loamy fine sand and sandy clay loam.

As for gypsic pararendzina, there are data on a number of solum horizons. Skeleton content is also high (in hor. A 21–46%) in gypsic pararendzina, decreasing downwards; thus, in AC it occurs less and in C at least. Regarding fine earth fractions, in gypsic pararendzina, similar to gypsic rendzic leptosol, the fine sand fraction is most common in hor. A (50–80%), followed by coarse sand (10–20%), silt (5–20%) and clay (5–17%). An analogous relation between the quoted fractions is also found in the other horizons. The physical sand share prevails over that of physical clay. The physical sand content increases in depth while the content of physical clay diminishes. This is a result of decay and dissolution in hor. A.

Two profiles of these soils belong to the class of loamy fine sand, and one profile falls into the class of sandy clay loam.

The high skeleton content, low clay content and dominance of physical sand over physical clay is a common feature of all soils formed from gypsum rocks in our country.

Chemical Properties

The results of the chemical properties of soils formed on gypsum rocks are provided in Table 5.

Content of $CaCO_3$ and $CaSO_4$

In the soils formed upon gypsum rocks, there is $CaCO_3$ (from 2.85–75.59%) in all horizons, the principal reason being that parental material (gypsum) is not pure and instead it contains $CaCO_3$.

In gypsic rendzic leptosol, $CaCO_3$ share in hor. A amounts to 13–75%. In these young soils, $CaCO_3$ is slightly washed. In gypsic pararendzina, hor. A is also very abundant in $CaCO_3$ (37–73%), and it is either unwashed or barely washed; hence,

Table 5. Chemical properties of soils formed on gypsum rocks in the Republic of Macedonia

No of profile	Horizon and depth cm	$CaCO_3$ %	$CaSO_4 \times 2H_2O$ %	pH		Humus %	Total N %	C/N	Availability of mg/100 g soil	
				H_2O	nKCl				P_2O_5	K_2O
Gypsic rendzic leptosol										
1	A 0-18	24.61	0	7.60	7.00	6.26	0.42	8.64	6.56	9.66
3	A 0-16	12.79	0	7.50	7.00	5.49	0.38	8.39	42.45	10.86
5	A 0-21	75.34	3,92	7.40	7.25	4.12	0.23	10.4	2.75	5.60
8	A 0-17	14.25	77,08	7.35	7.20	1.56	0.08	11.3	1.83	3.20
Gypsic pararendzina										
2	A 0-19	36.89	0	7.55	7.25	6.19	0.42	8.55	7.33	9.26
2	AC 19-32	75.59	1.53	7.55	7.35	3.57	0.24	8.58	23.15	4.02
6	A 0-15	73.30	2.95	7.25	7.15	6.38	0.35	10.6	2.38	7.60
6	AC 15-24	16.70	65.74	7.45	7.30	1.08	0.07	8.86	2.20	2.40
6	C 24-50	17.10	77.24	7.40	7.20	0.34	0.02	9.90	2.02	2.00
6	C 50-80	10.18	84.28	7.40	7.25	0.30	0.02	8.65	1.28	1.20
7	A 0-15	63.12	16.89	7.40	7.25	3.95	0.19	12.1	2.02	6.00
7	AC 15-28	3.34	88.92	7.50	7.45	1.19	0.07	9.86	0.18	1.60
7	C 28-43	2.85	92.72	7.40	7.25	0.57	0.04	8.27	0.18	1.20

in the lower profile section it occurs less. One of the reasons for this state could be that the lower horizons are extremely rich in $CaSO_4$, so that $CaCO_3$ percentage is rather reduced.

With reference to $CaSO_4$ content in gypsic rendzic leptosol, in two profiles it is absent from hor. A, in the third profile its presence is negligible, and it is abundant only in a single profile. Gypsum absence may be caused by its heavy washing due to greater solubility.

In gypsic pararendzina, the difference in gypsum content can be monitored along the profile depth. In prof.2 it has been washed by hor. A and in AC it is found only with 1.5%. In the remaining two profiles gypsum has been heavily washed, so its occurrence in hor. AC is multiple. The higher the gypsum content, the lesser the $CaCO_3$ content (relative depletion). It becomes apparent that hor. A has been exposed to gypsum washing for the longest period of time.

Soil reaction

The reaction in water in all soils formed on gypsum rocks ranges within narrow limits between 7.25 and 7.60. It is only hor. A of prof. 6 that has a neutral reaction whereas in all other horizons in all soils formed on gypsum rocks it is faintly alkaline.

In all studied assays, the reaction in nKCl ranges within narrow limits between 7 and 7.45. In gypsic rendzic leptosol, the interval is smaller (from 7.00 to 7.25). It is specific that the disparity between pH H_2O and pHn KCl is greater (0.5 to 0.6) in gypsic rendzic leptosol not comprising gypsum compared to that containing gypsum (0.15).

In gypsic pararendzina, pH nKCl in hor. A ranges between 7.15 and 7.25. These values ascend in depth. In hor. A of gypsic pararendzina, the difference in values of pH H_2O and pH nKCl ranges between 0.10 до 0.30. Such small variations are not the case in other soils in our country.

Humus Content

The humus content in gypsic rendzic leptosol varies from 1.6 до 6.3. It is inconsiderable (1.56%) only in prof.8 whereas in the other three profiles it is higher (4.12–6.26%).

In gypsic pararendzina, the humus content in hor. A is rather high (from 3.95 to 6.38%) in our circumstances since these soils are not cultivated. The humus content rapidly declines in depth.

Content of Nutrients

In soils on gypsum rocks rich in $CaCO_3$ + $CaSO_4$ there is less silica residuum providing water and nutrients for plants, which is the reason why the content of nutrients (except for Ca and S) in them is lower.

The total nitrogen content in gypsic rendzic leptosol varies between 0.08 and 0.42% and it is contingent on the humus content. Hor. A of gypsic rendzic leptosol is very rich (prof. 1 and 3), rich (prof. 5) and medium-rich (prof. 8) in total nitrogen. The identical horizon of gypsic pararendzina is very rich (prof. 2 and 6) and medium-rich (prof. 7) thereof.

The proportion of C/N in hor. A of gypsic rendzic leptosol varies from 8.4 to 11.3, and in gypsic pararendzina it varies from 8.6 to 12.1.

According to Al method, gypsic rendzic leptosol in hor. A is poor in easily available phosphorus (prof. 1, 5 and 8) and medium-rich (prof. 3), and all gypsic pararendzina is poor thereof.

As regards the content of easily available potassium, all profiles of soils formed on gypsum rocks are poor.

The content of exchangeable ions and the humus composition will be presented in a separate paper.

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УСЛОВИ ЗА ОБРАЗУВАЊЕ, ГЕНЕЗА, ЕВОЛУЦИЈА, КЛАСИФИКАЦИЈА И НЕКОИ СВОЈСТВА НА ПОЧВИТЕ ОБРАЗУВАНИ ВРЗ ГИПСЕНИ СТЕНИ ВО РЕПУБЛИКА МАКЕДОНИЈА

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Во овој труд се проучени условите за образување, генезата, еволуцијата, класификацијата, морфолошките својства, механичкиот состав и хемиските својства на почвите образувани врз гипсени стени во Република Македонија.

Почвите се образувани на планински релјеф со стрмни наклони врз гипс и анхидрит. Во подрачјето доминира топлата континентална клима со слабо влијание на медитеранската клима. Овие почви се јавуваат под брдски пасишта кои се флористички доста сиромашни и се одликуваат со мала покровност. Со уништување на природната шумска вегетација и со интензивна испаша на брдските пасишта што останале по тоа уништување е предизвикана силна ерозија на почвата. Од нашите проучувања констатиравме дека врз гипсени стени се образувани гипсени црници и гипсени рендзини. И двата почвени типа се одликуваат со лесен механички состав со преовладување на физичкиот песок. Карбонатите се присутни во двата почвени типа во сите почвени проби, додека во некои почвени проби гипсот е целосно промиен.

Клучни зборови: услови за образување; генеза; еволуција; класификација; гипсени стени; гипсена рендзина; гипсена црница