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Geochemistry of carbonatic/sulphatic soils in the southern Angara region, Russia

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ABSTRACT

The geochemistry of carbonatic/sulphatic soils of the southern Angara region is distinguished for its uniqueness as regards macro-as well as microelements. According to contents of some elements, the territory represents a contrasting positive geochemical anomaly: the soils are enriched above the average concentration (hereinafter referred to as Clarke) in Ca, S, Cl, P, Sr, Zn and Cu. But according to contents of many other elements, such as Rb, K, Ba, Cr, Ga, Zr, Ti and Pb, including lanthanides (Y, La, Ce, Pr and Nd), it is the territory of negative anomaly. Gleyic solonchaks are particularly strongly depleted, perhaps due to leaching the elements. Soils develop peculiar bonds between elements. Strong enrichment in P and Sr depends on sulfur accumulation in soils. Potassium depletion is accounted for by a deficiency of alumosilicates. Ba content decreases with an increase in the amount of calcium in the soil. The content of lanthanides depends directly on the amount of alumosilicates and indirectly on the content of carbonates. There is a difference in the geochemistry of separate lanthanides. A deficiency of chromium is particularly clearly pronounced in gleyic solonchak. A deficiency of zirconium is accounted for by a shortage of its main carrier, i.e. titanium, the content of which in soils is below a Clarke.

Introduction

The geochemistry of carbonatic/sulphatic soils has attracted considerable attention because of the difference in the genesis of carbonates (primarily calcite) and gypsum. Carbonates are produced both biologically and physic-chemically as a result of a shift in hydrocarbonate-calcium equilibrium. Gypsum often has a chemogenic origin, and gypsified solonchaks are characterized by exceptionally low fertility. On the other hand, gypsum is used widely in improving soda solonchak and solonetz soils [1]. It was demonstrated recently that gypsum decreases water-solubility of phosphorus thus retarding eutrophication of water bodies [2,3].

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The specific character of these calcisols/gypsisols implies that they had formed on red-colored Cambrian rocks which occur in the Nukutskii, Balaganskii and Osinskii districts of Irkutsk regoin, Russia. We studied the carbonatic/sulphatic soils on red-colored Cambrian deposits in the Nukutskii district of Irkutsk region, coordinates are the same [4]. In this district, gypsum is being mined on an industrial scale.

Calcium carbonic gypsum occurring in this area is formed when closed water bodies are fed by brooks and water flows during wet seasons. These flows transported to the lakes salts and suspended particles of lithogenic gypsum from eroded gypsum-bearing rocks. This process continues also to date.

Carbonatic soils mostly occur on hill tops, while carbonateness is accompanied by sulfate content on the hill slopes. In the depression, the situation is also complicated by two factors. First, material losses by erosion from the summits are responsible for a clearly pronounced binary character of the soil in the depression. Second, the humidification factor has a significant role in this case.

The geochemistry of these peculiar soils is poorly understood. Having excessive Ca and S contents, the soils can be depleted in many other elements. This remains to be further explored. In studying the geochemistry of the carbonatic/sulphatic soils, we analyzed separately the contents of the main and rare chemical elements.

We assign to the main elements those, the content of which in soils exceeds 1000 mg/kg. Of special interest among them are the elements, which form part of the mineral carriers of the rare elements. They are Al_2O_3 (as a component of clay minerals), Fe_2O_3, CaO, SO_3, and P_2O_5. Their form and content determine the degree of accumulation and fixing of many rare elements. The rare elements include those, the content of which does not exceed 1000 mg/kg.

Here, we seek to ascertain the main and rare elements with or in which the carbonatic/sulfatic soils are enriched or depleted. By analyzing the statistical bonds with the main elements, it is possible to determine the factors that are responsible for enrichment or depletion of carbonatic/sulphatic soils with and in the rare elements. Finally, an attempt will be made to determine the way in which a local humidification influences the content of chemical elements in gleyic solonchak.

The objective of this paper is to identify the geochemical characteristics of arid sulphatic soils and gleyic solonchaks in the southern Angara region, Russia.

Objects for study

In this study, attention was focused on three carbonatic/sulphatic soils that had formed on red-colored Cambrian rocks in the forest-steppe zone of the southern Angara region. Two sections were established on the southern steppizated slope (profiles 2 and 3) facing the right bank of the Zalarinka river, and in the floodplain of the Zalarinka river (profile 4), of the left tributary of the Angara, in the Nukutskii district of Irkutsk region; the schematic map of the territory is provided in Fig. 1. It is a hilly, eroded territory, with a widespread occurrence of gullies.

Particle-size distribution, organic carbon content, pH_{H_2O} values and color in the CIE-L*a*b* system are provided in Table 1. The soils show an alkaline-neutral reaction; pH is about 8. The soils show largely a heavy loamy particle-size content. The soils differ in moisture content, which is due to their topographic location. Most of the soil names are taken from the 2006 World reference base for soil resources [5].

The calcisol (profile 2) was exposed on the hill top. The coordinates of the section are: latitude – 53°41′28.16″, and longitude – 102°44′16.87″. The system of horizons is AJ1-AJ2-BM-BCA-Cca. The upper light-humus horizon, AJ1, is 11 cm in thickness. It is brownish-reddish in color, has a coarse chestnut-lumpy-silty structure, medium-sized loam, dense, dry, fragments of rock and rubble, carbonate concretions, penetrated by roots. Light-humus horizon AH2 lies beneath it, at a depth of 11–22 cm. Dense, dry, light loam brownish-reddish in color; there occur whitish carbonate tongues and concretions, and fragments of gypsum. The structural-metamorphic horizon BM (8 cm in thickness) is below. It is underlain by the accumulative-carbonic horizon BCA that inherited the red color of rock; its thickness is 19 cm. The Cca layer of carbonatic red-colored rock lies beneath it. The soil is dry throughout the entire depth. In soil color system CIE-Lab the soil consistently increases in redness (a*) with depth from 4.1 to 8.2. It effervesces throughout its depth in the presence of HCl.

The calcisol/gypsisol (profile 3) was exposed at a distance of 9 m from profile 2 in the middle part of the slope in the saddle. The coordinates of profile 3 are: latitude – 53°41′28.11″, and longitude – 102°44′16.66″. The system of horizons is AJ-AJs-BMs-BCAs-D1ca,s-D2ca,s. The upper light-humus horizon AJ1 is 6 cm in thickness. It is brownish-reddish in color; silty-lumpy, dense, dry medium-sized loam. Beneath it, there occurs the light-humus salic horizon AJs at a depth of 6–27 cm. It is underlain by the structural-metamorphic salic horizon BMs 13 cm in thickness. Below it is the accumulative-carbonatic salic horizon BCAs that inherited the red color from rock; it is 13 cm in thickness. This is underlain by the layer of carbonatic red-colored material, D1ca,s, 17 cm in thickness. Below is the second, lighter, layer of carbonatic red-colored material, D2ca,s. In soil color system CIE-Lab the soil shows a high, almost constant redness at a depth of $a^* = 7.5$–8.5. It effervesces throughout the entire depth in the presence of HCl. The soil is binary in character: silt content decreases from 33 to 17% at a depth of 53 cm. The soil is dry throughout the depth. Carbonates occur in the form of tongues and pseudo-mycelium. Residual carbonates are represented by fragments of Cambrian rocks in the lower soil horizons. The accumulative-carbonatic horizons are: lithogenic-illuvial (profiles 2 and 3), and illuvial-hydrogenic (profile 4).

Gleyic solonchak (profile 4) was exposed in the flood-lain of the Zalarinka river 190 m from profile 3 and 50 m from the river channel. The coordinates of profile 4 are: latitude – 53°41′27.33″, and longitude – 102°44′14.96″. The system of horizons is AU-S-Cca,s-D1g,ca,s-D2g,ca,s-D3g,ca,s. The upper dark-humus horizon AU is 12 cm in thickness. It is gray in color, has a coarse-lumpy structure, medium-sized loam, compact, humidified; there occur white small concretions, and undecayed plant remains. Below is the solonchak horizon