Mineralogical and Micromorphological Investigations of the Salt Accumulations in Solonchak of Uzbekistan

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Abstract: In this paper, we consider the results of special investigation into the composition and properties of different types of salt accumulations sampled from the surface salt crust of Solonchak in Uzbekistan. The soil profiles were dug in the dry delta of the Zeravshan River in Uzbekistan. The surface salt crust of the crusty Solonchak can be differentiated into three major morphological types. The particular minerals were diagnosed with a help of X-ray diffraction and thermogravimetric (TG), microscopes Olympus BX 51 and SEM. Chemical analyses of water extracts from these types of the crust suggest that all of them consist of a mixture of sodium and magnesium sulfates and chlorides with somewhat different Cl/SO₄ ratios. The appearance of high alkalinity in the first type of the crust might be related to the activity of microbiota concentrated in certain microzones. Micromorphological and mineralogical investigations showed that each morphological type of the salt crust is characterized by its own paragenetic association of mineral salts with a predominance of sodium and magnesium sulfates: thenardite, mirabilite, and bloedite (astrakhanite); more careful examinations with the use of TG and SEM techniques have shown the presence of glauberite, polyhalite, and gypsum. It is important that only a combination of different investigation techniques makes it possible to identify different minerals of salts in their mixture and suggest a reliable interpretation of the obtained data.

Key Words: Solonchak, Salt minerals, Spatial and vertical heterogeneity of the salt accumulations.

1. Introduction

Despite a considerable interest of researchers in the effect of soluble salts on the properties and functioning of soils in arid regions, the micromorphology and mineralogical composition of different salt accumulations have so far been examined insufficiently in Russia, which is explained by methodological and technical difficulties arising during the study of these unstable formations. The studies of mineral associations in salt crusts have been performed in many parts of the world (Driessen and Schoorl, 1973; Mees and Stoops, 1991; Mees and Tursina, 2010; Poch et al., 2010). In this paper, we consider the results of special investigation into the composition and properties of different types of salt accumulations sampled from the surface salt crust of a crusty solonchak in Uzbekistan. The main goals of our study were to (1) typify the morphologically different parts of the salt crust, (2) determine the chemical properties of different types of salt accumulations, (3) determine the mineral composition of salt crusts using mineralogical and submicromorphological analyses, and (4) give a comprehensive characterization of the diversity of crystal chemistry features of salt minerals.

2. Materials and Methods

Spatial and vertical heterogeneity of the mineralogical composition and fabric of the salt crust of a crusty solonchak were studied in detail. The soil profiles were dug in the dry delta of the Zeravshan River in the central part of an old-irrigated Karakul oasis in Uzbekistan. Morphologically different parts of the salt crust were sampled in midday and hermetically sealed in glass tubes. Field descriptions of the salt crust morphology were complemented by binocular studies. The particular minerals were diagnosed with a help of X-ray diffraction (XRD) and thermogravimetric (TG) methods using an XZG-4a diffractometer (Carl Zeiss Jena, Germany) and a Q-1500 D derivatograph (F. Paulek&t K'.). The samples were also analyzed under SEM JSM-6610LV a combined with a system of X-ray microanalysis INCAx-act. The analysis of water extracts (1:5) from salts crusts was performed to determine the chemical type of salinity.

3. Results

A preliminary typification of surface salt accumulations of the crusty solonchak was performed on the basis of data on their morphological properties, such as the thickness, density, color, and the amount of associated silicate mineral particles. As a result, three morphological types of the surface salt crust were distinguished. The salt crust of the first type is most widespread on the surface of studied solonchak. This crust is compact, hard, grayish white in color, and about 5 cm in thickness. Its surface is very uneven, with a tarnish of silt particles; it has its own nanotopography with an amplitude of about 3 cm. Micro- and mesomorphological features of the
The salt crust of the first type is characterized by the presence of trona crystals, which are typical of this type of salt crust. It is known that the identification of the mineralogical composition of salts represents a challenge in the case when one deals with a mixture of differently soluble salts and insoluble (silicate) minerals. Only a set of chemical, mineralogical, micromorphological, crystallographic, and crystal-chemistry methods make it possible to obtain reliable data and suggest their interpretation. An interesting and surprising fact revealed in our study is the simultaneous presence of thenardite and mirabilite in the uppermost layer and the presence of mirabilite in the middle layer of the salt crust of the first type. In general, our results are in agreement with the results obtained by Driessen and Schoorl (1973) during the study of salt efflorescence in the Great Konya Basin, Turkey. The same mineral association (thenardite, mirabilite, and bloedite) has been registered in both cases. Data on phase transitions of sodium and magnesium sulfates with due account for temperature conditions and concentration of sulfate ions in the solution containing also sodium chlorides make it possible to assume that different layers of the thick salt crust of the first type were formed under different hydrothermic conditions. The lowering of winter temperatures (to subzero values) in the upper soil layer leads to a considerable decrease in the solubility of sodium sulfates (from 92 to 11 g/L). This creates conditions for the synthesis and stability of mirabilite. In the summer, mirabilite in the uppermost layer is partly transformed into thenardite. Under conditions of very low summer precipitation, both minerals can exist together in the uppermost crust layer. Below, the predominance of mirabilite is registered. Another characteristic feature of the salt crusts studied is the presence of different crystallographic forms of the same mineral in different locations. Thus, perfect prismatic thenardite crystals are formed in microhollows, whereas cavernous and half-destroyed thenardite crystals are present in the crust occupying the main surface of the solonchak. Chemical analyses of water extracts showed that the salt crust of the first type is distinguished from the other two types by its high alkalinity (both total alkalinity and bicarbonate alkalinity). This feature may be caused by the living activity of microorganisms concentrated in the microzones within the lower part of the crust.

4. Conclusions

The surface salt crust of the studied Solonchak can be differentiated into three major morphological types. Chemical analyses of water extracts from these types of the crust suggest that all of them consist of a mixture of sodium and magnesium sulfates and chlorides with somewhat different Cl/SO$_4$ ratios. Micromorphological and mineralogical investigations showed that each morphological type of the salt.
crust is characterized by its own paragenetic association of mineral salts with a predominance of sodium and magnesium sulfates: thenardite, mirabilite, and bloedite (astrakhanite); more careful examinations with the use of TG and SEM techniques have shown the presence of glauberite, polyhalite, and gypsum.

It is important that only a combination of different investigation techniques makes it possible to identify different minerals of salts in their mixture and suggest a reliable interpretation of the obtained data.

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