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SALT AND GYPSUM PEDOFEATURES AS INDICATORS OF SOIL PROCESSES

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Pedofeatures of salts and gypsum in arid and semi-arid soils indicate the salinization process and its dynamics. Mineralogical and morphological features of these pedofeatures, their distribution in the soil profile as well as confinement to individual components of microstructure are indicators of soil processes, both modern and relict. The paper presents the results of a comprehensive morpho-mineralogical analysis of the newly formed salt and gypsum pedofeatures in saline soils in the south of European Russia and Cis-Baikal region as well as Transcaucasia, Central Asia, Kazakhstan and Mongolia.

Key words: saline soils, salt and gypsum pedofeatures.

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Research on diagnostic features, genesis and distribution of salt and gypsum pedofeatures in soils is being conducted in many countries worldwide (Gerasimova et al., 1992; Lebedeva and Kust, 2015; Minashina, 1958; Feofarova, 1950, 1958; International Symposium on Soils with Gypsum, 1996; Poch and Herrero, 1988; Poch et al., 2010; Verba and Yamnova, 1997).

The main research target at the present time is the micro- and submicro-morphology of salt and gypsum pedofeatures in different types of soils. Analysis of available literature sources reveals unresolved questions about interconnection between the morphology and genesis of salt and gypsum pedofeatures, the regimes of soil functioning and the elementary soil-forming processes within saline and gypsum horizons.

Soils of different natural regions (desert, semi-desert and steppe) with different chemical properties and degrees of modern and relic salinity have been studied. The study objects include: (1) in desert – Hydromorphic Sulphate Solonchaks (salt crusts), Automorphic Chloride Solonchaks and Gypsic Solonchak in the extremely arid and true deserts (Mongolia), Gypsic Solonchak in sub-boreal desert (Kazakhstan); (2) in semi-desert – Chloride Solonchak (western part of Cis-Caspian

Lowland), Light-coloured Crusty Solonetz and Chestnut Solonetzic soils (clayey plain of Khvalynskaya in the south of European Russia), Serozem-Meadow Gypsic soil in sub-tropical semi-desert (Golodnaya Steppe, Uzbekistan), Sodium-Sulphate-Chloride Solonchak in arid sub-tropics (Ararat valley in Armenia, Transcaucasia); (3) in steppe – Gypsic-Calcareous soils and “gazha” (gypsum-bearing deposits) in dry steppe (South Urals), Gypsic Solonchak on gazha in forest-steppe (Cis-Baikal).

The morphological types of salt pedofeatures (crusts, druses, veins, etc.), the form and size of salt crystals within these pedofeatures, their abundance, mineralogical nature, confinement to certain components of macro- and microstructure and distribution within soil profile – all these are the indicators of modern and relic soil processes.

The morphological assessment of salt pedofeatures includes the following parameters: (a) hardness (softer than silicates), (b) colour (mostly white with yellowish or crème hue), and (c) solubility in water (soluble salts) or 10% HCl (gypsum and carbonates, the latter with effervescence).

At the micro-scale the pedofeatures of calcium carbonate, gypsum and salts are clearly separated from adjacent soil mass by composition.

The most informative morphological and mineralogical indicators of soil salinization include the following: (a) the mineralogical composition of salts, (b) the morphological diversity of salts and their confinement to certain elemets of microstructure, and (c) relationships between the morphology of salts and the type of salinization as well as salt crystallization conditions.

The mineralogical and micromorphological assessments of salt pedofeatures are simultaneously conducted at the four different scales in the following order:

1) Macro-scale – detailed describtion of soil pit and salt pedofeatures in field and identification of salt cristals, druses, etc. The salt pedofeatures differ from the silicate soil minerals by their physical and chemical properties: (a) density (less dense), (b) colour (mostly white with yellowish or crème hue), and (c) solubility in water (soluble salts) or 10% HCl (gypsum and carbonates, the latter with effervescence). The presence of main anions and cations (Cl, SO_4, Na) is tested by reactions with specific chemicals.

2) Meso-scale – description of soil samples of undisturbed consistency under a binocular microscope (magnifications from 10 to 100). Salt crystals, druses and aggregates larger than 0.025 mm are separated from the silicate parts of soils for studying their sizes, shapes and confinement to certain components of the meso-structure such pores and the surface of structural units. There are four methods of mineralogical diagnostics of salts: (a) immersion, where the mineral in question is diagnosed by its optical properties – refractive index, optic axial angle 2v, extinction angle, cleavage, fracture and crystal habit, (b) X-ray diffraction, with identification of crystals by their X-ray diffraction patters, (c) thermogravimetric analysis and (d) computed tomography.

3) Micro-scale – description of thin sections of undisturbed samples under a polarizing optical microscope (magnifications from 100 to 500). This method allows characterising the soil fabric, micro-aggregates, pores, salt pedofeatures and their confinement to individual components of microstructure. At this scale of observation, the optical diagnostic of minerals is based on their optic properties – refractive index, optic axial angle 2v, extinction angle, cleavage, fracture and crystal habit (like in immersion).

4) Submicro-scale – description of undisturbed samples under a scanning electron microscope (magnifications from 200 to 50000) with X-ray micro-analysis. At this scale one can determine (a) detailed characteristics of salt aggregates, (b) salt crystal distribution over micro-structure components (aggregates, pores, mineral grains and plant debris) and (c) chemical composition and mineralogical nature of individual salt crystals. The mineral diagnostics are based on crystallographic parameters as well as chemical composition of crystals.

Analysing salt and gypsum pedofeatures in saline hydromorphic and automorphic soils of sub-boreal deserts of Mongolia and Kazakhstan, semi-deserts of Cis-Caspian Lowland, Central Asia and Transcaucasia and steppes of Trans-Baikal territory and South Urals allowed identifying significant differences in their morphological structure as well as chemical and mineralogical composition depending on salinity type and the degree of hydromorphism.

The chemical composition of pedofeatures in desert soils revealed the presence of only neutral salts (chlorides, sulphates and gypsum) in automorphic soils, but both alkaline and neutral salts in hydromorphic soils. Mineralogically, the automorphic pedofeatures contained halite, thenardite, astrakhanite, glauberite and hydroglauberite, while the hydromorphic pedofeatures contained the above minerals and also mirabilite and borax. Micromorphologically, salt and gypsum pedofeatures in automorphic soils are diagnosed as being inherited from the parent rocks and currently re-distributed within the soil profile. A specific feature of microstructure of lithogenic Solonchaks is the presence of optically oriented clay only within the upper part of the profile, which is indicative of an active participation of salts in the reorganization of microstructure. Halite pedofeatures are represented by non-crystalline salty-clayey mass (Fig. 1). The lower horizons are characterized by fragmented consistency typical for the rock. The morphology of halite crystals is principally different from above, being represented by (a) aggregates consisting of regular cubic crystals and (b) fibrous aggregates consisting of fibres (Fig. 2). These two specific forms of halite pedofeatures originate from the rock, where they crystallized under stable conditions in the past (by contract to distorted habits of halite within the crust above).

The automorphic soils are characterized by the abundance of cryptocrystalline calcite and occurrence calcite pseudomorphs after gypsum as well as irregularly shaped salt aggregates (Fig. 3). All these microfeatures are indicative of decomposition and metamorphism of gypsum within automorphic soil profile.

The hydromorphic soils are characterized by the presence of calcareous clay films at the surface of salt aggregates, which occur within small pores, and the loosening action of thenardite. There are morphologically different types of thenardite crystals: aggregates of

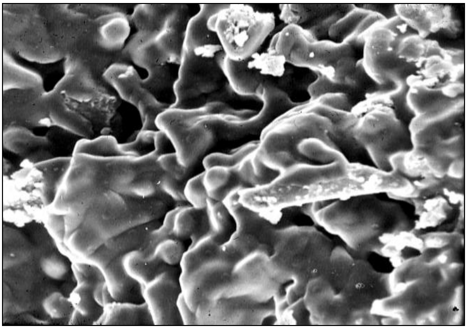

Fig. 1. Pedogenic halite (SEM).

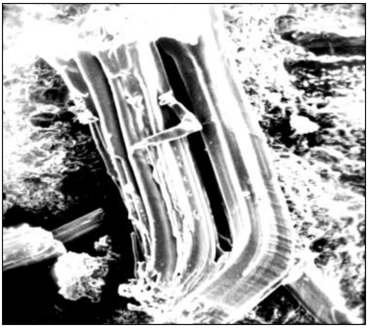

Fig. 2. Lithogenic halite (SEM).

prismatic crystals being a part of salt crust and loose concentrations of rounded crystals of secondary thenardite re-crystallized from mirabilite. The thenardite horizon porosity is 47% (with 23% of open pores) and the mirabilite horizon porosity is 70% (with 100% of open pores). The micromorphological features of hydromorphic soils are indicative of a progressive salt accumulation taking place at the present time, with the salt composition depending on the ground water composition. The morphology of these pedofeatures and their confinement to individual components of microstructure are indicators of soil-forming processes. In the upper horizons, gypsum is concentrated mainly within intrapedal mass and has pseudo-rhomboidal crystal shapes, with swallow-tail twins being common. Deeper, near the ground water table, single-layered and multi-layered gypsum coatings and infillings of hydrological origin are formed within soil pores. The other form of gypsum – idiomorphic crystals – originate from calcium of carbonates during decarbonatization of adjacent plasma.

The chemical composition of pedofeatures in hydromorphic soils of deserts (Transcaucasia) is determined by the ground water composition of soda type. A soda-sulphate salinization is characterized by the peptization of plasma and the occurrence of thenardite and halite in
A microscopic study of samples from gazha soils of Cis-Urals steppe has revealed that their main gypsum-bearing horizon consists addition to soda-related minerals (soda, thermonatrite and nahcolite). Specific shapes of crystals – irregular and rounded – can serve as a diagnostic feature of re-crystallized crystalohydrates.

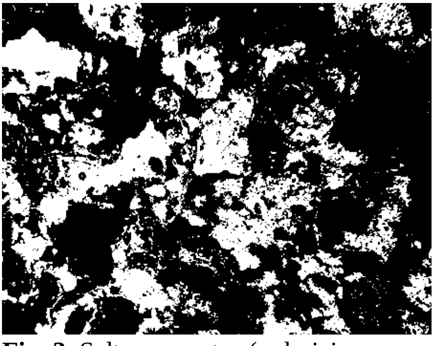

Fig. 3. Salt aggregates (polarizing microscope), NX.

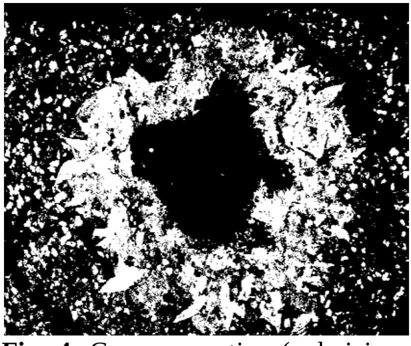

Fig. 4. Gypsum coating (polarizing microscope), NX.

mainly of very small individual crystals of pseudo-rhombohedral gypsum, with gypsum druses being rare. The mineralogical analysis has confirmed a mono-mineral composition (gypsum). There are features of gypsum transformation with no salt accumulation. Gazha soils also develop of gypsum-bearing parent rocks in Trans-Baikal region. Their microstructure (particularly, the shape and size of gypsum crystals and the fabric of gazha horizon) confirms sedimentary origin of gypsum. The distribution of gypsum and calcite crystals within the soil profile demonstrates the input of gypsum from the gazha parent rock into the modern soil profile.

A comparative morpho-mineralogical analysis of the newly formed salt and gypsum pedofeatures has revealed that the intensity of their accumulation in hydromorphic soils is different in different natural regions, although their crystallization develops in accordance with general principles of mineral formation. The shape of salt and gypsum pedofeatures does not depend on natural regionalization, but it is determined by the conditions of mineral formation depending on the degree of soil hydromorphism. Salt and gypsum pedofeatures differ by crystal shapes and sizes, solubility and degree of hydration (crystalohydrates) and, therefore, react differently to changes in soil-forming conditions and can serve as indicators of salinization processes.

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