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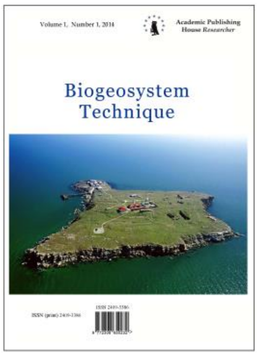

UDC 630

Salt Neoformations in Soils of Central Mongolia

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Abstract

Diagnosis of saline neoformations is an important characteristic of the solid phase of arid soils, since the formation of salt accumulations is closely related to the problem of the genesis of soil profiles, and to the possibility of their agricultural use. The formation of certain morphological forms (impregnation, powdering, concretion forms, cutans, individual crystals, their aggregates, etc.) depends on many factors – the granulometric composition of the soils, the type and characteristics of the water regime, the nature of the evaporation of solutions and the temperature differences. We considered the composition and forms of salt neoformations in the soils of Central Mongolia, in which unique conditions for their manifestation are realized. The most important of them are sandy coarse-grained granulometric composition with a high content of coarse sandy particles and clastic material, extremely low water flows, relatively small temporal variability in soil moisture and extreme daily and annual temperature differences. The use of modern methods of electron microscopy revealed that in the studied soils slow crystallization and the small number of nucleation centers lead to the formation of predominantly needly-like crystals and "brushes" of salts – calcite, barite and astrachanite. Furthermore, in these circumstances, and halite forms a highly unusual for him needle-like crystals. For soils this phenomenon observed for the first time. Also the formation of acicular salt crystals in the investigated soils was noted due to specific thermo-hydrological phenomena and was explained by the forces arising under these conditions.

Keywords: saline soils, aggregates, salt formations, Mongolia.

1. Introduction

Mongolia has an arid and cold climate due to its geographical settings of inland and mid-latitude highlands. A high moisture deficit, low humidity and low levels of incident energy characterize it. Despite 260 days (more than 3000 hours) of sunshine, total heat units above 10°C rarely exceed 2000 and in some areas are less than 1000. Snow cover is very light so soils are completely frozen in the winter. The depth of soil freezing (1.6–1.7 m for the Gobi Desert and 3.2–3.5 m for the forest steppe) during mid-October to early April (Jambaajamts, 1989). Precipitation is generally low, ranging from less than 50 mm per year in the extreme south (Gobi desert region)

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to just over 500 mm per year in limited areas in the north. The average countrywide precipitation is about 200–230 mm that is almost exactly matched by the annual evapotranspiration: roughly 90–95 % of this amount returns to the atmosphere through evapotranspiration (Batjargal, 1992; Li et al., 2007; Nandintsetseg, Shinoda, 2011; Robock et al., 2000; Zhang et al., 2005). This is an extremely high evapotranspiration rate compared to other regions of the world. Only about 3 % of the total annual precipitation infiltrates into the soil to replenish aquifers and becomes potentially available as a water resource in the form of soil moisture or ground water. This proportion is very low compared to the water balances of other regions in Asia in which not less than 30–40 % of precipitation remains available (for example, the Amur river basin, Russia). Because of the continental climate, fluctuations in temperature are extreme, both annually and diurnally. Fluctuations can be as high as 30 °C in single day and the difference between average winter low temperature and summer high temperature in excess of 50 °C as compared to 25 °C range in Europe (Batjargal, 1992).

The features of soil formation processes in different natural and landscape zones of Mongolia are not identical, but are characterized by some common specificities, the most important of which are the slowness of weathering and clay formation processes and, as a consequence, the widespread distribution of soils of sandy granulometric composition with a high content of coarse sandy particles and clastic material. In addition, the small thickness of the soil profiles and their humus strata, the slowness of the biological cycle, the shallow penetration of the root systems into the soil, the nature of the soil-forming rocks (crushed stone and sanding) limit the manifestation of all water flows (Nogina, Dorzhgotov, 1982). The thickness of the moistured layer rarely exceeds 20–30 cm (Chizhikova, 1988; Yamanaka et al., 2007). The seasonal change in soil moisture was small (≈10 mm), which is consistent with the studies of Nogina et al. (1975), Robock et al. (2000), Ni-Meister et al. (2005) and Nandintsetseg, Shinoda (2011), and vertical profiles are almost constant with depth (Robock et al., 2000; Ni-Meister et al., 2005). Thus, soil moisture in Mongolia is characterized by relatively small temporal variability. Over Mongolia, the available soil moisture was about 30 % of the soil field capacity during the warm season, while, in the Gobi Desert zone, the available soil moisture was close to the wilting point throughout the year (Nandintsetseg, Shinoda, 2011; Nogina et al., 1975).

Zonal soils of the main natural zones of Mongolia are characterized by the absence of salinity, since the parent rocks are mainly represented by a low-power gravelly eluvo-deluvium slightly carbonate, not saline and without gypsum. Groundwater is deep and does not affect the processes of modern soil formation and salt accumulation. The special situation is occupied by closed depressions and soils that fill geological faults. These are areas of accumulation of surface and underground runoff, soils are often saline in these conditions. Within the Gobi Desert, red-colored deposits of Cretaceous age of various granulometric composition (from sand to clay) are quite widely developed, mostly in the saline (Polynov, 1952; Pankova, Rubtsova, 1983). Saline soils are not common, but their area is near 10.5 % (Pankova, 1986; Bespalov, 1951). They are genetically associated with ancient accumulations of salts and/or with the processes of modern salt accumulation, confined to the zone of modern geochemically subordinate hydromorphic landscapes.

Diagnosis of saline neoformations is an important characteristic of the solid phase of arid soils, is under the influence of soil solution equilibrium (Endovitsky et al., 2016; Batukaev et al., 2016), since the formation of salt accumulations is closely related to the problem of the genesis of soil profiles, and their presence in soils influences the possibility and methods of their agricultural use. The composition of salt accumulations depends on the composition of soil-forming rocks and soil solutions and the depth of groundwater. In their turn, with a close mineralogical composition, their (morphological) shape and dimensions can be completely different: impregnation, powdering, concretion forms, cutans, individual crystals, their aggregates, etc. The formation of certain morphological forms depends on many factors – the granulometric composition of the soils, the type and characteristics of the water regime, the nature of the evaporation of solutions and the temperature differences, the mode of soil processing and moistening (Kovda, 1946; Minashina, 1978; Shoba et al., 1983; Kalinitchenko, 2016; Kalinitchenko et al., 2014, 2016).

The purpose of this work is to consider the composition and forms of salt neoformations in the soils of Central Mongolia, in which unique conditions for their manifestation are realized – a sandy coarse-grained (granular) granulometric composition and low variations in soil moisture under extreme daily and annual temperature differences.

2. Materials and methods

Study area and soils

The study was focused on the soils of Central Mongolia: Gobi desert and Steppe Region (Fig. 1A). The warm period (April – October) is the main time of the soil evolution processes, the Gobi Desert and Steppe regions under study are characterized by the following temperature regime, the amount of precipitation and soil moisture (0–50 cm layer). According to the Institute of Meteorology and Hydrology of Mongolia for the period 1986–2005, the mean values of temperature, precipitation, and soil moisture for these zones are 14.2±6.7 °C, 118±4 mm, 16.1±2.9 mm and 12.0±6.7 °C, 199±8 mm, 25.7±3.5 mm, respectively (Nandintsetseg, Shinoda. 2011). Soil samples were taken to the depth of the soil moistening (0–20 cm) in September 2016.

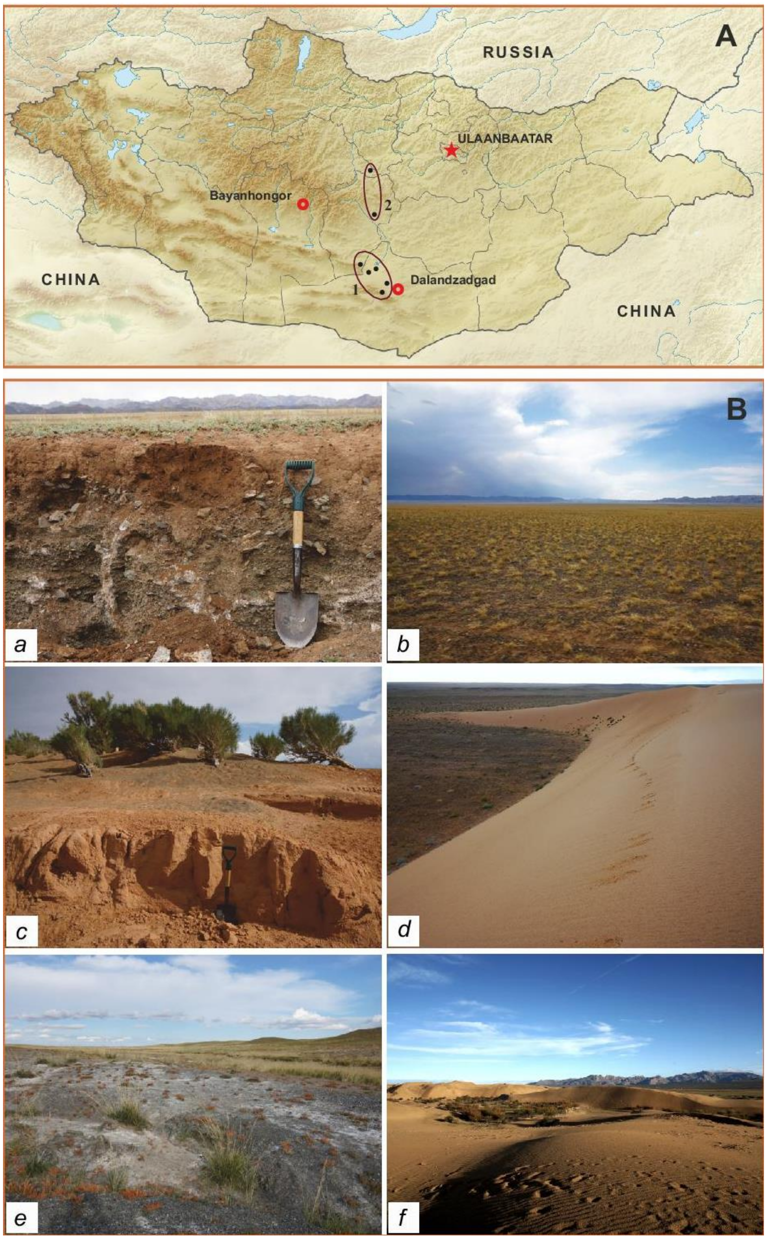

Fig. 1. A. Sketch map of location of study areas (region1 and region 2). **B.** Typical landscapes of sampling sites: *a–d* – Gobi Desert Zona (region 1, sites 1–3 and 5 respectively); *e*, *f* – Steppe Zone (region 2, sites 6 and 8 respectively). Field photos, for other explanations see text

Gobi Desert Zone

Site 1. The northern alluvial fan descending from Züün Saihan ridge, at 2 km down from its foot, the bank of erosional gully about 1 m deep. Coordinates of the soil profile: latitude –

43°33′17.3″ N, longitude – 104°06′57.3″ E, altitude – 1968 m. Soil type: Endosalic Calcisols Yermic, loam (WRB 2006). The soil sample 1.1 was taken from the soil surface layer 0–20 cm, sample 1.2 – the same location at 20–35 cm depth, as a parent material (Fig.1B*a*)

Site 2. The base of alluvial fan from Züün Saihan ridge, where the topography is getting nearly flat, at about 17 km north of the foot of the ridge. Coordinates of the soil profile:

43°40′46.7 ″, 104°09′53.0″, 1513 m. Soil type: Endosalic Calcisols Sodic, sandy; depth of soil sampling 0–15 cm (Fig.1B*b*)

Site 3. The Bayan Zag saxaul forest, the edge of the eolian sand dunes, at 3 km northwest from the famous Flaming Cliff dinosaur site of Berkey and Andrews. Coordinates of the soil profile: 44°10′11.7″, 103°42′15.8″, 1242 m. Soil type: Sand grandular; depth of soil sampling 0–15 cm; iron in the form of films on the grain surface (Fig. 1Bc) and there is soda, which gives a high pH and electrical conductivity (Table 1).

Site 4. The northern piedmont plain of the Gurvan, where the locals plant vegetables, such as carrots, potato, melon onion. Coordinates of the soil profile: 44°05′47.9 ″, 103°32′57.3″, 1306 m. Soil type: Endosalic Calcisols Sodic, sandy; depth of soil sampling 0–15 cm.

Site 5. The active eolian sand dune within the piedmont hills of Gobi Altay range, top. Coordinates: 44°13′37.2″, 103°18′48.1″, 1132 m. Soil type: Sand; depth of sampling 0–10 cm (Fig.1B*d*)

Steppe Zone

Site 6. The narrow zone with solonchak soil along the NE trending fault. Coordinates of the soil profile: 46°02′98.7″, 103°52′38.2″, 1478 m. Soil type: Haplic Solonchaks Aridic, sandy loam; depth of soil sampling 0–15 cm (Fig. 1Be)

Site 8. The ancient active sand dunes of Elsen Tasarhai. Coordinates of sampling site: 47°20′12.4″, 103°41 ′ 04.8 ″, 1268 m; depth of sampling 0–5 cm. Sand (Fig. 1B*f*).

A brief description of some physical and chemical properties of soils is given in Table 1.

Table 1. Brief description of the physical and chemical properties of soils

No	Soil type	Depth, cm	pH	σ* (μS/cm)	Content of granulometric fractions, %		Gross composition of fine earth, %			
					< 2 mkm	2–50 mkm	SiO_2	Al_2O_3	Fe_2O_3	Na_2O
	Gobi Desert (region 1)									
1	Endosalic Calcisols Yermic (WRB, 2006), loam	0–20	8.0	161.9	4.7	45.5	56.54	12.44	6.72	2.55
2	Endosalic Calcisols Sodic, sandy	0–15	8.1	88.6	0	27.2	58.60	12.60	6.31	2.60
3	Sand grandular	0–15	9.9	382.0	0	3.3	81.95	8.75	1.61	2.43
4	Endosalic Calcisols Sodic, sandy	0–15	8.5	154.0	0	7.2	72.64	10.13	2.95	2.80
5	Sand	0–10	7.4	10.6	0	0	72.34	12.64	1.58	4.58
	Steppe (region 2)									
6	Haplic Solonchaks Aridic, sandy loam	0–15	9.7	270.0	11.6	58.9	60.93	14.61	2.58	3.73
8	Sand	0–5	6.4	11.3	0	0	84.79	6.62	1.40	2.06

Note. N – Sampling site, * – specific electrical conductivity of water extraction

Methods of study

The study was based on granulometric and gross analyzes, which were supplemented by electron microscopic studies (SEM analysis). The SEM analysis was carried out on a scanning electron microscope VEGA 3 LMH (TESCAN, Czech Republic). For the survey, the samples (preliminary grinded and sieved through a 2-mm sieve) were prepared by the method of pouring, Pt-spraying, magnification - up to 20,000. A backscattered electron detector (BSE detector) was used for the analysis of phases with a high atomic number. When images are acquired using a BSE detector, phases with a high average atomic number are reflected in contrast more vividly than those with a lower atomic number. The X-max 80 energy dispersive spectrometer (Oxford Instruments, Great Britain) was used to analyze the elemental composition of the most representative regions. The capture area of the microanalysis is about 1 μm in diameter. If the analyzed object has smaller, the result of the analysis is distorted due to the influence of the surrounding matrix or the carbon table of the device.

The granulometric composition of the samples as a whole was determined by the sieve method (particle size distribution <2; 2–10; and >10 mm), fine earth fraction <2 mm by laser diffraction (particle size distribution from 0.01 to 2000 μm) on a size analyzer Particles SALD-2300 (SHIMADZU, Japan) (Fraunhofer, 1817; Vadjunina, Korchagina, 1973; Shein et al., 2006; Wolform, 2011). The total composition was determined by the X-ray fluorescence method (Pioneer S4, Bruker AXS, Germany) using the silicate analysis technique.

3. Results and discussion

Particle-size distribution data

Before characterizing the salt neoformations in the studied soils, we introduced data on particle-size distribution, which is one of the fundamental features of soils and sediments, in many ways determining their physical and chemical properties. Additionally, particle-size distribution is a source of important information about the origin of sediments (alluvial, marine, and eolian), their transport history and sedimentation conditions (van Genuchten et al., 1999; Buurman et al, 2001; Eshel et al., 2004; Pachepsky, 2004; Rawls, 2004; Iatrow et al., 2007; Segal et al., 2009).

Figure 2 shows generalized curves of particle-size distribution (differential and integral) for studied soils. Thus, there is clearly a much more pronounced differentiation of the ancient deflated dunes on the differential curves (Fig. 2*a*, site 8) as compared to the younger sand dunes (Fig. 2*b*, site 5). If the fraction of fine sand (100–250 μm) is the most representative for the first, then for the latter – the fraction of medium sand (250–500 μm). In turn, solonchak (Fig.2*c*, site 6) and foothill soil (Fig. 2d, site 1) are characterized by much smaller differentiation of the particles in size and a high content of silt and clay particles <50 μm – 70 and 50 % respectively (Fig. 2*c*, *d*).

Changes in the granulometric composition of soils from the foothills to the plain are extremely interesting. So if in the foothills in the soaking layer a high content of dust (a wide peak with a maximum of 60 μm) is accompanied by a significant content of clay fraction (a clear peak of 0.3 μm), then differentiation of particles by size is noted for plain soils (Fig. 2*e*, *f*). On the differential figures, peaks of fractions of medium dust, fine (100–250 μm) and medium (100–250 μm) sand are clearly distinguished. The peak for medium dust of the garden soil is much lower. It is believed that with wind erosion by a strong wind over long distances (hundreds and thousands of kilometers), particles of <50 μm in size (Igarashi et al., 2011) are mainly transported. But, apparently, the bulk of the transported particles is medium dust and smaller particles (<10 μm).

The gross composition of fine earth clearly corresponds to the granulometric analysis: sands (sites 3, 5 and 8) contain significantly more SiO_2 (72–85 %) than foothills and plains (57-73 %). The content of Na_2O and K_2O indicates a high content of Na- and K-feldspars, the content of which is maximal in young sands (site 5) – 4.6 and 3.6 %, respectively. The solonchak (site 6) is characterized by an increased content of Na and S, chlorine is also present (according to the XRD analysis, the AXS method), but its content is significantly lower than the accuracy of its determination by the silicate method, by which the samples are analyzed.

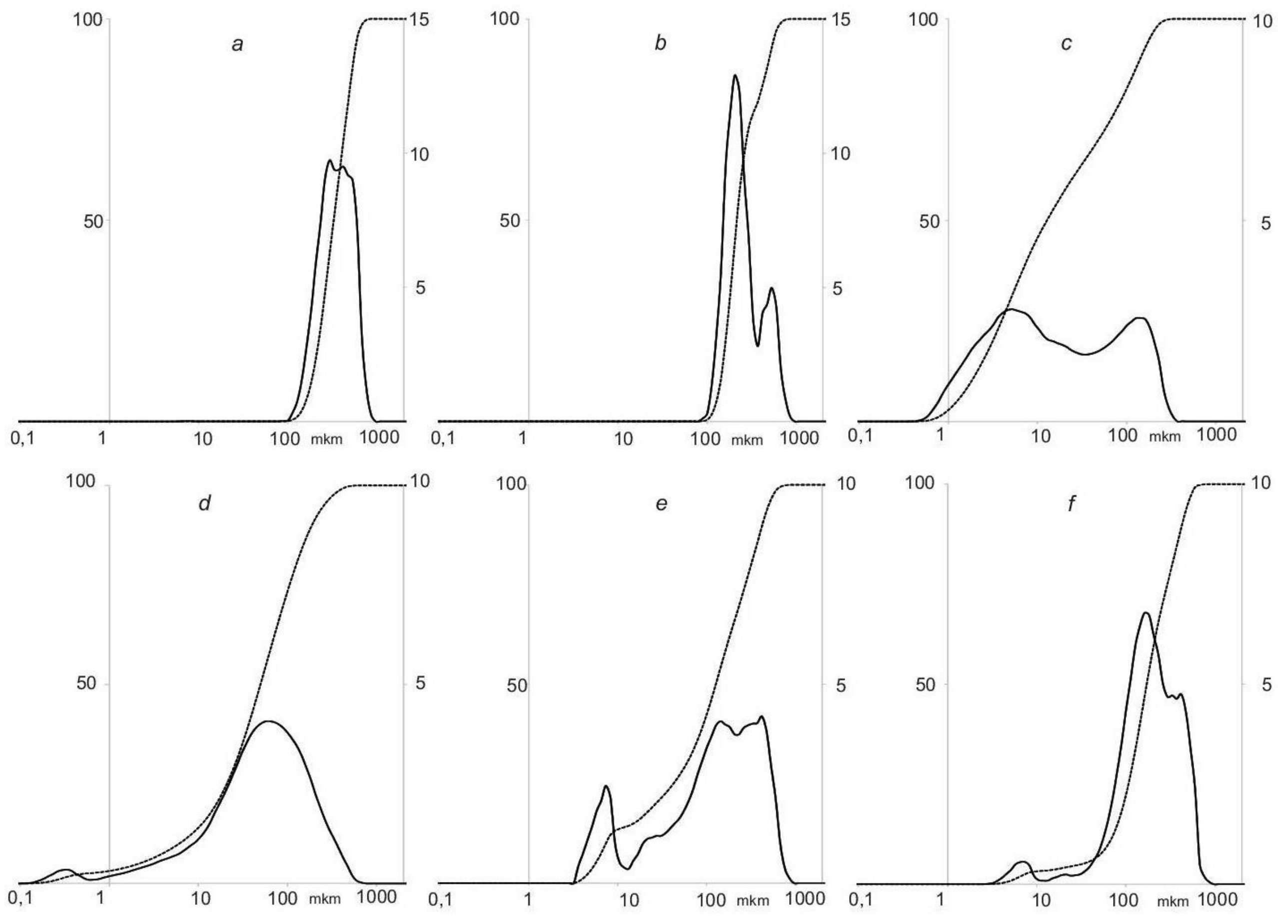

Fig. 2. Particle-size distribution in the soils (the left axis of ordinates is the percentage of particles for cumulative curves; the right axis of ordinates is the percentage of particles for differential curves): *a* – relatively young sands of barkhan site 5; *b* – old sands, site 8; *c* – solonchak, site 6; *b*–*d* – desert soils of point 1, 2 and 3 (4)

Consider the manifestations of salt growths in the studied soils. Carbonates in the Gobi Desert soils form clayey-sandy in composition, rounded and rather loose microaggregates up to 300 µm in size (Fig. 3*a*, *b*, sites 1 and 2). Microaggregates formed in irrigated lands (Bulgan Garden, site 4), denser, larger size 100–700 µm (Fig. 3*c*, *d*). However, their number is much smaller: the grains of primary minerals predominate in the soil. Microaggregates are characterized by the presence of round pores with a diameter of 10–20 µm. The vesicular voids are originated as a result of the changes in the moisture and temperature conditions (McFadden et al., 1998; Lebedeva et al., 2016) for watering and drying.

On the surface of grains of primary minerals larger than 2 mm and predominantly more than 10 mm, calcite forms large enough cutans (fur coats) from intergrown needles that grow perpendicular to the surface of the grain. The thickness of the cutans reaches 300 µm (Fig. 3*e*, *f*). Similar formations, consisting of acicular crystals, are more rounded due to weathering, occur in the reddish sands of site 3 (Fig. 3*g*). In addition to cutan from needle crystals, "calcite brushes" are formed. Their thickness is substantially less than 100 µm, and they consist of separate thin (up to 2–3 µm) acicular calcite crystals (Fig. 3*h*).

Needle calcite crystals are found in soils quite often, but needle-like crystals of NaCl were first discovered in soils (Fig. 4*a*, *b* – solonchak, site 6). It could be assumed that they can be formed by the roots of plants (Fig.4*b*), but the formation of "brushes" (Fig. 4*a*) with a high degree of probability makes it possible to assert that in these conditions it is precisely needle-like crystals that can grow. Most likely, they are formed on the surface of large enough primary particles. On the surface of clay microaggregates, only NaCl crystals of cubic form are encountered (Fig. 4*c*, *d*), which is most typical for crystals of this salt. Needle crystals of radial-ray packing on the surface of microaggregates and grains of primary minerals also form astrachanite – $Na_2Mg(SO_4)_2$ – sodium and magnesium double sulfate (Fig. 4e, f). Sodium sulfate Na_2SO_4 (thenardite) on the soil surface forms only microcrystalline accumulations of anhydrous salt (Fig. 4g), it is possible that in these conditions due to desiccation, needle crystals, characteristic of $Na_2SO_4 \cdot 10H_2O$ (mirabilite) crystal hydrate, are simply not stable. In addition, soda was diagnosed in the composition of clay-salt microaggregates (minerals 2: 1 of illite-smectite group) (Fig. 4h).

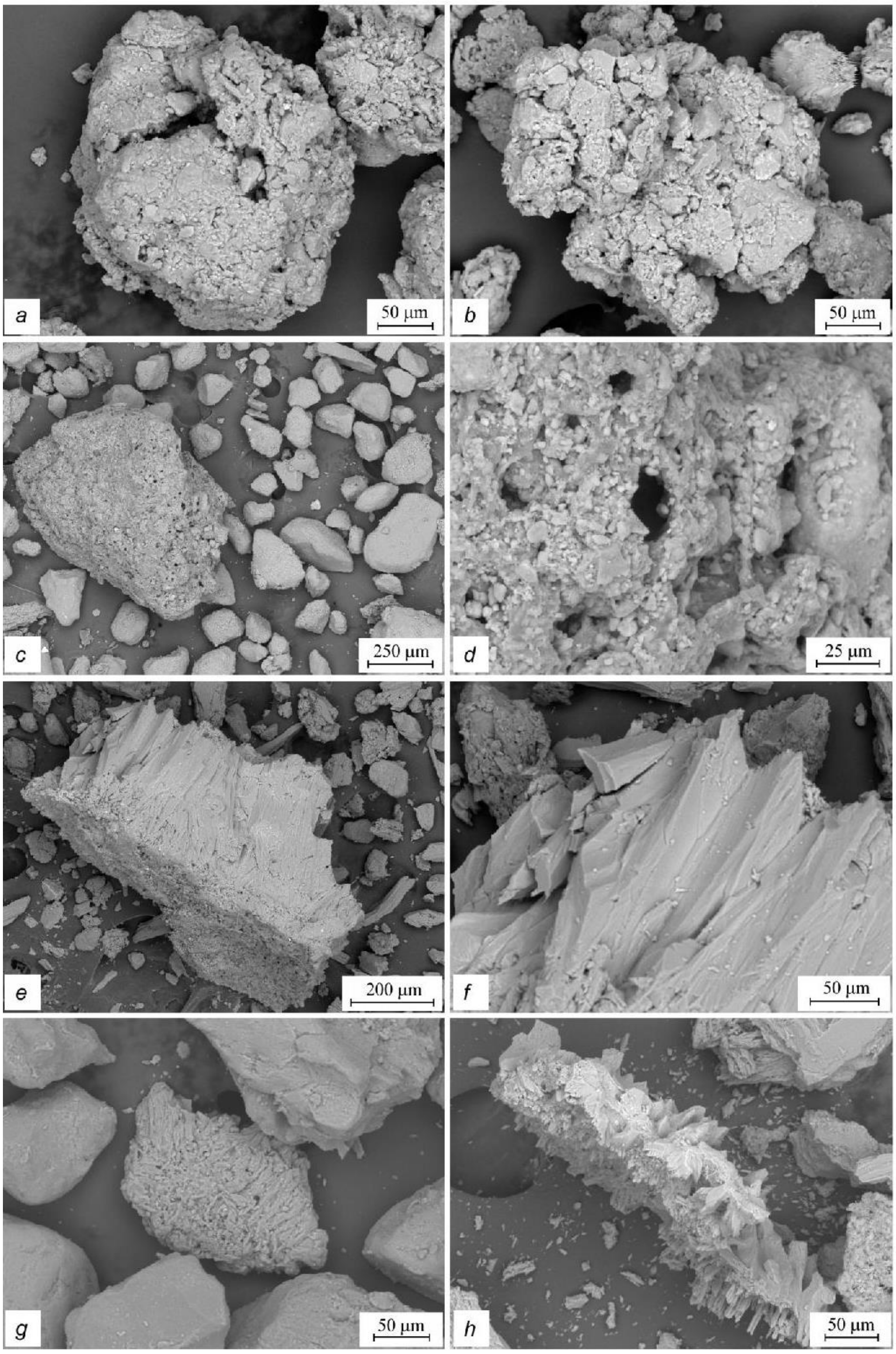

Fig. 3. Micrographs of calcite microaggregates (*a-d*) and needle precipitates of calcite (*e-h*): *a* – site 1 (0–20 cm layer); *b* – site 2; *c* – site 4, *d* – increased fragment of microaggregate; *e*, *f* – site 1 (0-20 cm layer) calcite from the surface of particles larger than 10 mm; *g* – site 3; h – site 1 (20-35 cm layer) calcite from the surface of particles larger than 10 mm (SEM, BSE-detector)

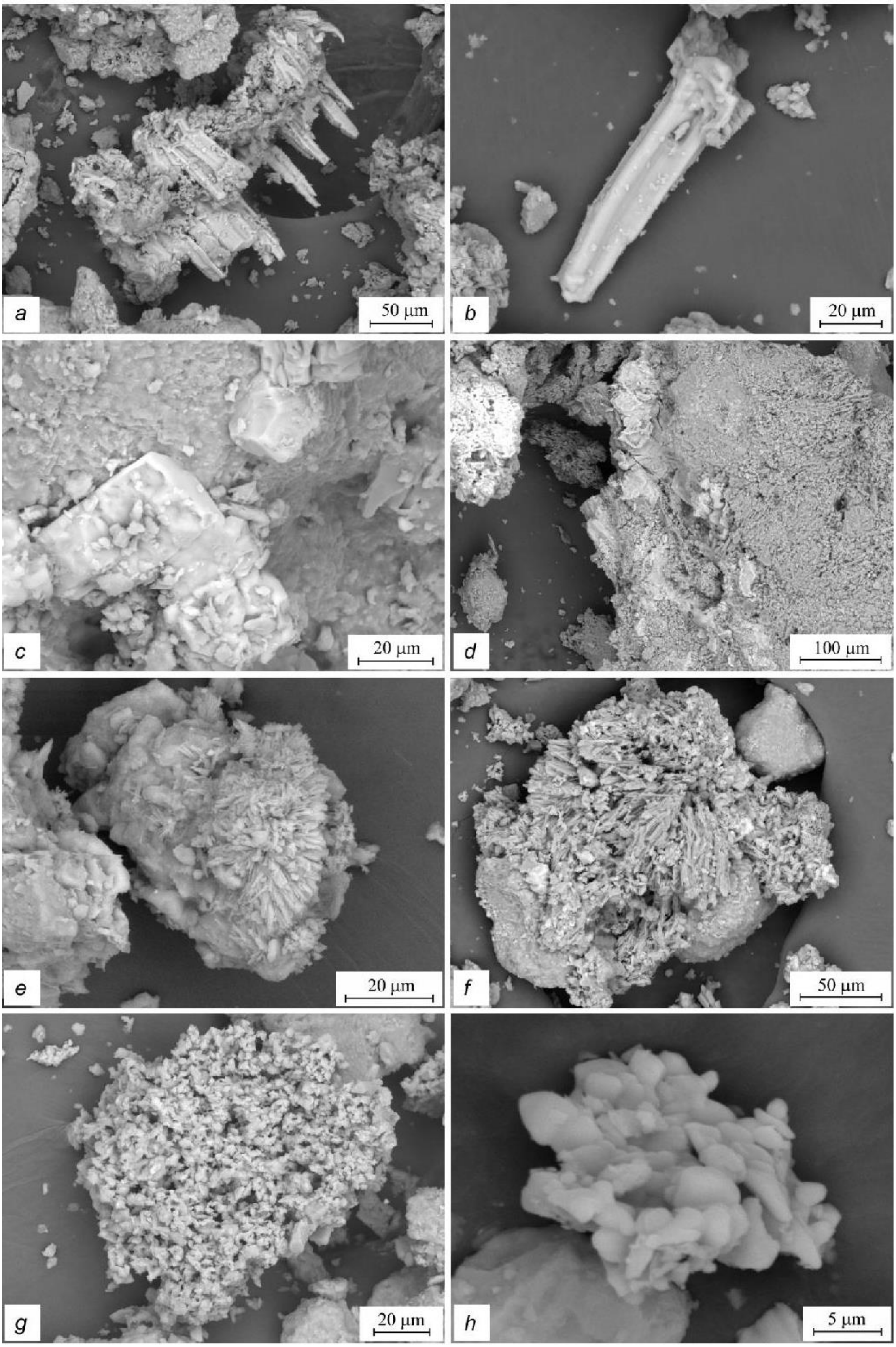

Fig. 4. Microphotographs of salt formations of solonchak (site 6): *a*, *b* – acicular crystals of NaCl; *c*, *d* – cubic crystals of NaCl and *e*, *f* – needle crystals of Na_2MgSO_4 on the surface of clay microaggregates; g – fine crystalline Na_2SO_4, *h* – microaggregate of soda and smectite crystallites (SEM, BSE-detector)

Soda was also found in sample 3 (red sands, eolian sand dune) in the calcite-clay (minerals 2: 1 of illite-smectite group) pseudomycelium (Fig. 5a). The latter holds together and retains the grains of the primary minerals. The presence of soda explains the extremely high pH values of ~10 of the aqueous extract of this sample, close to the pH values of the solonchak. The alkaline reaction of the medium involves the formation of Fe- and Mn-Fe-oxide "coats" (films) on the surface of microaggregates and primary particles (Fig. 5b, c). The high content of soda (and, correspondingly, the pH of the water extract) is due to the high content of Na-feldspars, the weathering of which leads to the formation of soda (Polynov, 1952). So, mosaic films were found on the surface of weathered (with the formation of parallel needles) grains of Na-feldspar, whose composition is close to the composition of pseudomycelium (Fig. 5d) according to the EDS analysis.

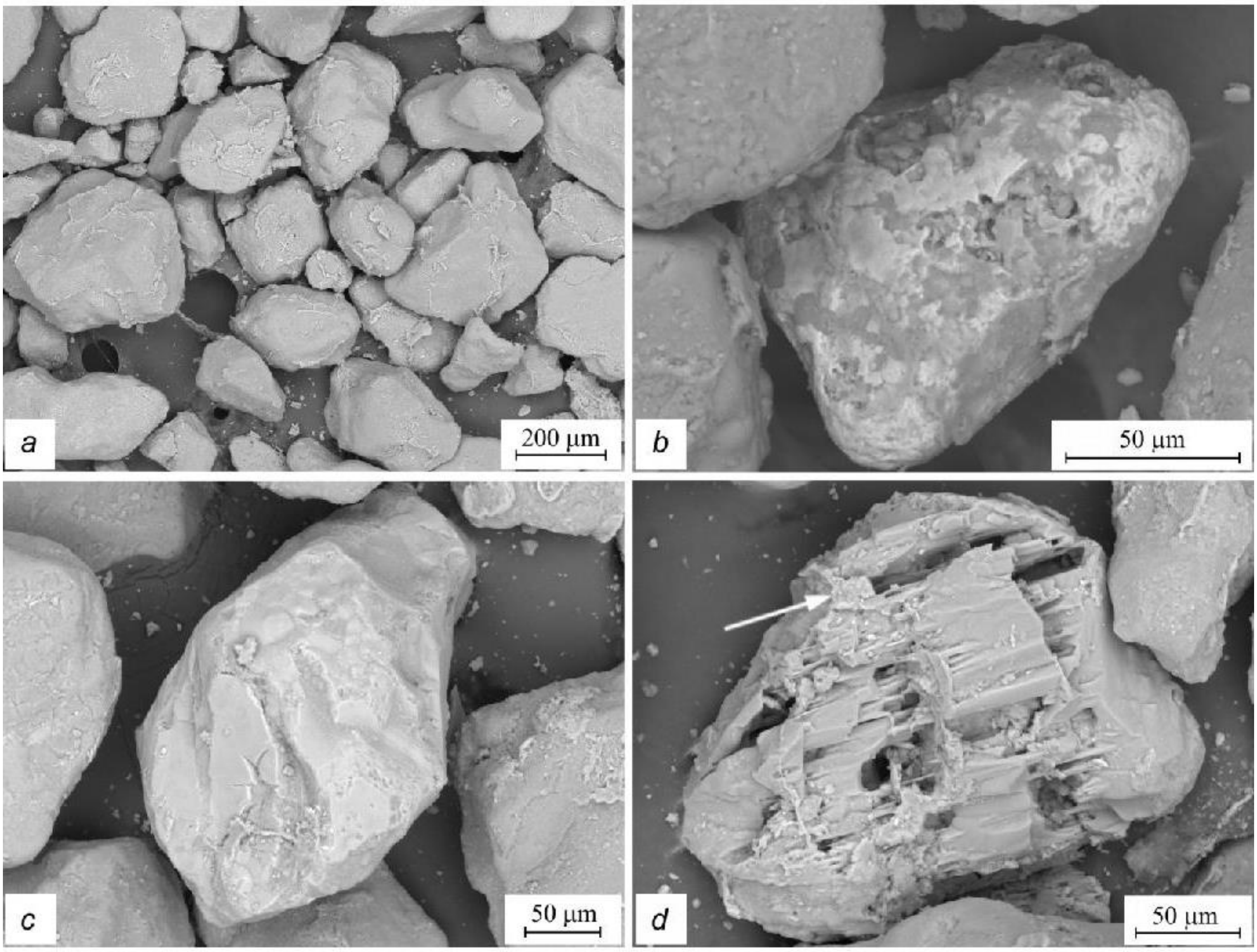

Fig. 5. Microphotographs of pseudomycelium (*a*) and "coats" from oxides of Fe (*b*) and Mn-Fe-oxides (*c*) on the surface of microaggregates and grains of primary minerals; weathered Na-feldspar (*d*) and soda-calcite-clay film (arrow) on its surface, site 3 (SEM, BSE-detector). For other explanations see text

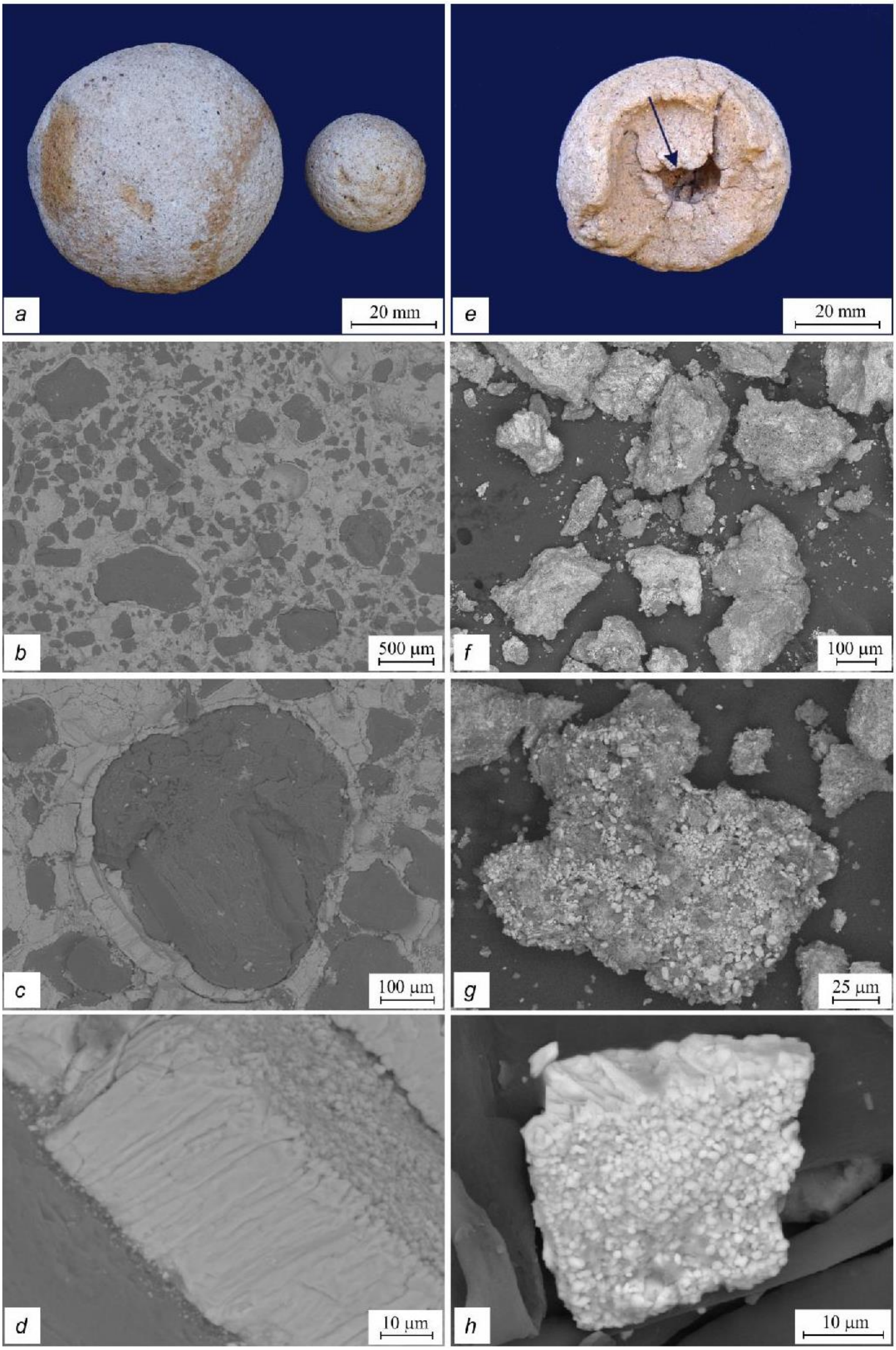

Fig. 6. Sand barite concretions (*a*, *e*, allow – the empty core of broken concretion) and microstructure of their body (*b*–*d*) and core (*f*, *g*): thin slice (b) and coatings of quartz (*c, d*); *f*, *g* – sandstone grains and clay microaggregate; *h* – soil barite formation (light microscopy – *a*, *e*; SEM, BS-detector – *b*–*d*, *f*–*h*). For other explanations see text

To explain the formation of acicular salt crystals in the investigated soils, let us turn to the natural "model" experiment – the formation of acicular barite crystals in sandy concretions, which we discovered in the vicinity of Site 5 (Kharitonova et al., 2017). Studied concretions mostly have spherical form and size up to 5 cm (Fig 6a). Concretion body is firmly cemented barite $BaSO_4$, its content reaches 50–55 % in a volume. Barite completely filled all space between sandstone grains (Fig. 6b). The clast grains are rounded by thin barite crystalized coating. Needle crystals grow perpendicularly to the surface (Fig. 6c, d), the isolation of such structures was diagnosed in soils – site 1, a layer of 20–35 cm (Fig. 6h). Their (coatings) expressiveness, the strength of the bonding with the grain, on which they are formed and corresponding preservation (under slicing of concretion) changes symbatically to coating size. The most endurable coatings are peculiar to the quartz grains. Maximal size barite coatings, which quartz grains are characterized, is 40 μm, potassium feldspar and plagioclase – 10 and 2–5 μm respectively. This is due to the degree of weathering of the surface of grains of minerals, of which quartz is the most stable. It should be noted that in comparison with coatings, the cement between the grains is more friable and is represented by fine-crystalline. In composition, coatings contain substantially less iron, then less homogeneous in composition and structure cement between the grains – up to 0.1 and 1–2 at. % respectively.

Concretion core with the size near 8 mm (Fig 6e), consists of separate poorly interconnected grains of quartz and feldspars. Besides, there are many clay microaggregates (minerals 2:1 of illite-smectite group) in the core, which size corresponds to the size of clast grains up to 200–250 μm (Fig 6f). The content of barite in the core is substantially less, than in the body of concretion. Apart from thin films on grains of clast minerals, barite is represented by fine lamellar crystallites up to 1–2 and 4–6 μm in the content of microaggregates (Fig 6g). The size and shape of barite precipitates are determined by the growth phase of concretion. The first phase of growth of concretion was very fast with insulation of the concretion core by cement. The second stage took place slowly, resulting in formation of barite coatings on clast grains (with a small amount of impurities) and the growth of the concretion due to the crystallization of barite (with the inclusion of iron oxide) between them (clast grains), and very slightly pushed them by crystallization pressure.

4. Conclusion

Thus, according to the results of a natural experiment, with rapid crystallization (the strong supersaturation of the solution with a change in its temperature and, accordingly, a change in the salt solubility) a large number of crystallization centers (in our case fine particles of clay minerals) lead to the formation of small xenomorphic (irregular shape) of the crystals. Conversely, with a slow crystallization and a small number of crystallization centers (in our case this is the surface of clastogenic grains), relatively large idiomorphic crystals are formed. In soils, not only their crystalline features, determine the shape of crystals of different salts but also by external factors – supersaturation, composition and temperature of the solution, its motion. In real soil conditions, many factors continuously change, which leads to a large number of morphological forms of crystals. However, with relatively constant environmental conditions, the Curie principle apparently works primarily: the shape of the crystals retains symmetry elements that, due to geometric selection, are common with the host matrix. Because of geometric competition, crystals, whose direction of maximum growth rate is normally located to the substrate, displace less well-oriented (Shafranovsky, 1954; Shubnikov, 1975). It should be noted that the formation of parallel needle structures during slow weathering of Na-feldspar does not contradict the hypothesis (conclusions) of needle-shaped salt neoformations in low-moistured soils.

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Солевые новообразования в почвах центральной Монголии

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Аннотация. Диагностика солевых новообразований является важной характеристикой твердой фазы аридных почв, поскольку формирование солевых аккумуляций связано с проблемами генезиса почв и определяет возможность их сельскохозяйственного использования. Формирование определенных морфологических форм новообразований (пропитка, присыпка, конкреции, кутаны, отдельные кристаллы, их агрегаты и т.д.) зависит от множества факторов – от гранулометрического состава почв, типа и характеристики водного режима, характера испарения и перепадов температур. Были изучены состав и формы солевых новообразований в почвах Центральной Монголии, которые характеризуются уникальными условиями эволюции. Наиболее важные из них – это гранулометрический состав почв с высоким содержанием грубых песчаных частиц и обломочного материала, низкое содержание почвенной влаги и относительно невысокая ее временная изменчивость, экстремальные перепады суточных и годовых температур. Использование электронной микроскопии показало, что в исследуемых почвах солевые новообразования представлены, главным образом, игольчатыми формами кристаллов кальцита, барита и астраханита и их своеобразными агрегатами – "щетками", что связано с малым числом центров кристаллизации (грубый гранулометрический состав почв) и замедленной кристаллизацией при небольших перепадах влажности. Кроме того, в этих условиях галит (хлорид натрия) образует весьма необычные для него игольчатые кристаллы. Это явление для почв отмечено впервые. Формирование игольчатых солевых новообразований в исследуемых почвах связано с термо- гидрологическими условиями территории.

Ключевые слова: засоленные почвы, агрегаты, солевые образования, Монголия.

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