

SOLONETZIC SOILSCAPES IN THE NORTHERN CASPIAN LOWLAND: LOCAL AND SPATIAL HETEROGENEITY OF PEDOFEATURES AND THEIR CHANGES IN TIME

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A comparative micromorphological analysis of soil fabrics within two- and three-component semidesert solonetz complexes formed within closed-drainage plains with different types of microtopography in the northern of the Caspian Lowland has been conducted. Micromorphological features of soils of most extensively studied three-component solonetz complexes having soil cover with a high degree of contrast are indicative of divergent evolutionary trends during the past half century. On the basis of these features, different directions of degradation of solonetzic and saline horizons are revealed. Although degradation of solonetz horizons is practically undetectable at a macro-scale, its micromorphological features are clearly manifested in parameters of aggregates, characteristics of coatings and types of salt pedofeatures. Common factors of solonetz evolution in nearby regions allow extrapolation of the micromorphological indicators of solonetz degradation to a wide range of objects including two-component solonetz complexes.

Key words: solonetz complexes, micromorphology, soil genesis and evolution.

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The complexes of solonetz (alkaline) soils within the Caspian Lowland are extensively studied ([Rode and Polsky, 1961](#); Ivanova et al., 1966; [Sizemskaya et al., 1989](#); [Sokolova et al., 2000](#); [Khitrov, 2004, 2005](#); [Konyushkova, 2014](#)). Their recent evolution trends starting from the Subatlantic Period have been identified ([Ivanov, 2006](#)). The development of solonetz complexes within semi-deserts is associated with almost extreme ecological conditions. The moisture deficiency and specific types of microtopography are generally recognized as the main factors forming soil and vegetation complexes.

The study area is characterized by sharply continental climate, with the annual evaporation (about 1000 mm) being much higher than the annual precipitation (291 mm within a period of 1952–2013). The mean annual temperature is 6.9°C, with a maximum of +42°C in summer and a minimum of –38°C in winter. The depth of soil freezing can reach one metre ([Biogeocenotic basis..., 1974](#)).

The objects of study belong to meadow-steppe solonetz complexes in the classification by [Ivanova and Fridland \(1954\)](#), because of the groundwater table depth of 4–8 m within the study area. Such complexes are known to have most dynamic development in connection with the Caspian Sea transgressions and regressions, fluctuations in the groundwater table and, possibly, changes in microtopography ([Konyushkova and Abaturov, 2016](#)).

The climate of the Caspian Lowland has been becoming increasingly more humid since the late 1970s, with a 50 mm increase in annual precipitation and a 70 mm decrease in evaporation during the warm season ([Sotneva, 2004](#); [Sapanov, 2007](#); [Sapanov and Sizemskaya, 2015](#)). These values seem small, but they make a huge impact on arid and semi-arid ecosystems with a generally poor natural drainage, where they cause wide-spread rising of the groundwater table ([Sokolova et al., 2000](#)).

Three-component meadow-steppe soil complexes with uneven microtopography include the following soils: (1) solonchakous solonetztes ([Field Guide..., 2008](#)) – Epialic Solonetztes ([WRB, 2014](#)) of microhighs;

(2) light-coloured chestnut soils (including saline and alkaline) ([Field Guide..., 2008](#)) – Gypsic Kastanozems (Sodic) ([WRB, 2014](#)) on microslopes;

(3) dark-coloured meadow chestnut soils ([Field Guide..., 2008](#)) – Mollic Kastanozemes ([WRB, 2014](#)) within microlows.

There are very few published data on soil fabrics within semi-desert solonetz complexes that occupy plains of different ages and have microtopography developed to different degrees and soil cover with different degrees of contrast. The existing publications are mostly devoted to soil fabrics of three-component meadow-steppe complexes characterized by uneven microtopography with deep microlows that occur within the Dzhyanybek Research Station of the Institute of Forest

Science of the Russian Academy of Sciences, where typical soils include solonchakous Solonetztes on microhighs, light-coloured chestnut (including alkaline and saline) soils on microslopes and meadow chestnut soils in microlows ([Polsky, 1961](#); [Rode et al., 1960](#); [Yarilova, 1966](#); [Bazykina, 1978](#); [Lebedeva and Gerasimova, 2009](#); [Lebedeva and Konyushkova, 2011, 2016](#)).

The aims of the present study include a comparative analysis of soil micro-features depending on the type of microtopography of solonetz complexes within the northern part of the Caspian Lowland and an early micromorphological diagnostics of soil-forming processes and evolutionary trends before their manifestation at a macro-scale.

OBJECTS AND METHODS

The three study sites – “Muratsai”, “Dzhanybek” and “Borsi” are characterized by different types of microtopography and soil cover (Fig. 1, Table).

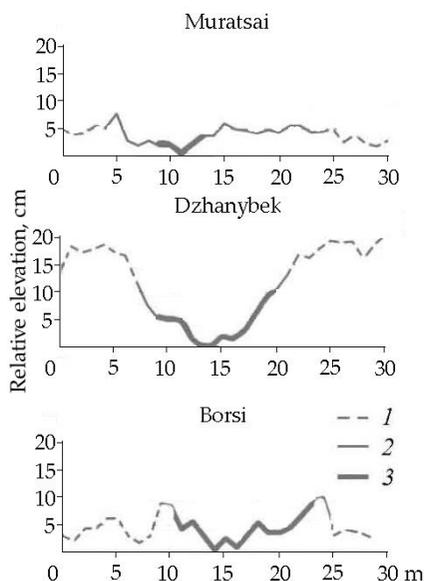


Fig. 1. Distribution of soils along microtopographic transects (leveling survey) at the study sites: 1 – solonetz, 2 – light-coloured chestnut soil, 3 – meadow chestnut soil (at Borsi and Dzhanybek) or chestnut soil (at the Muratsai site).

Brief characteristics of the study sites

Study sites	Coordinates	Height a.s.l., m	Soil pits no. (soil abbr.* in brackets)	Microtopography type; Degree of contrast in soil cover of solonetz complex	Age of the sites (Chepalyga, Pirogov, 2006)
Muratsai	49.049 N, 47.156 E	+25	3K-5 (SN ₀), 3K-6 (Ch)	Slightly uneven microtopography with shallow microlows; soil cover with a low degree of contrast	Middle Khvalynsk (about 16 kyr)
Dzhanybek	49.399 N, 46.810 E	+26 (+28)	10 pits (SN ₀ ; SN ₁ ; SN ₂ ; SN ₃); 6 pits (Ch ₁); 2 pits (MCh)	Uneven microtopography with deep microlows; soil cover with a high degree of contrast	
Borsi	50.108 N, 47.496 E	+48	3K-2 (SN ₀); 3K-1(MCh)	Level microtopography without microlows; soil cover with a high degree of contrast	Early Khvalynsk (about 17 kyr)

*Soil abbreviations: MCh – dark-coloured meadow chestnut soils; SN – solonetz, with the following varieties; SN₀ – crust-like (<5 cm); shallow (SEL within 5–10 cm); SN₂ – medium (SEL within 10-15 cm); SN₃ – deep (SEL > 15 cm); Ch– light-coloured chestnut soils ([Field Guide, 2008](#)).

There are three different types of microtopography at the study sites: slightly uneven microtopography with shallow (5–10 cm) microlows at Muratsai, uneven microtopography with deep (15–30 cm) microlows at Dzhanybek and level microtopography without microlows at Borsi.

The types of soil cover structure within the study sites are as follows. The Muratsai site is characterized by soil cover with a low degree of contrast, dominated by solonetz and other alkaline soils with very few (less than 5%) of deeply-desalinated soils, the latter being confined to microlows. The Dzhanybek site is characterized by soil cover with a high degree of contrast and three-component soil complexes with a significant percentage (25–50%) of deeply-desalinated meadow chestnut soils confined to microlows. The Borsi site is characterized by generally similar soil cover (with a high degree of contrast and three-

component soil complexes with 25–50% of deeply-desalinated meadow chestnut soils) as Dzhanybek, but deeply-desalinated soils occur at the same microtopographic level as solonetztes.

A typical profile of solonchakous solonetztes in desert biogeocenoses of all the three sites consists of clearly defined horizons: SEL, BSN, BCAs,cs and Cca,s. The crust-like and shallow solonetztes have the SEL surface horizons, while the medium and deep solonetztes have the AJ+SEL surface horizons ([Field Guide, 2008](#)). Light-coloured chestnut soils of dry steppe biogeocenoses consist of the following horizons: AJ, BMK, BM, CAT and Cca. The deepest microlows within steppe biogeocenoses are occupied by the most leached soils that are referred to as chernozem-like or meadow chestnut soils with the AY, AYBMK, BMK and Cca horizons.

The site locations are shown on the map compiled on the basis of digital elevation data (Fig. 2). There is a distinct elevated area (above 35 m a.s.l.) of so-called “Dzhanybek Ostanetz”, which was not inundated during the Talginsk sea transgression of the Middle Khvalynsk Period (about 16 kyr BP). The Borsi site is located within the Dzhanybek Ostanetz. The Dzhanybek site is located near the Elton salt lake, away from the Dzhanybek Ostanetz.

According to the existing data, the main chemical and physico-chemical properties of solonetz complexes within the Dzhanybek site

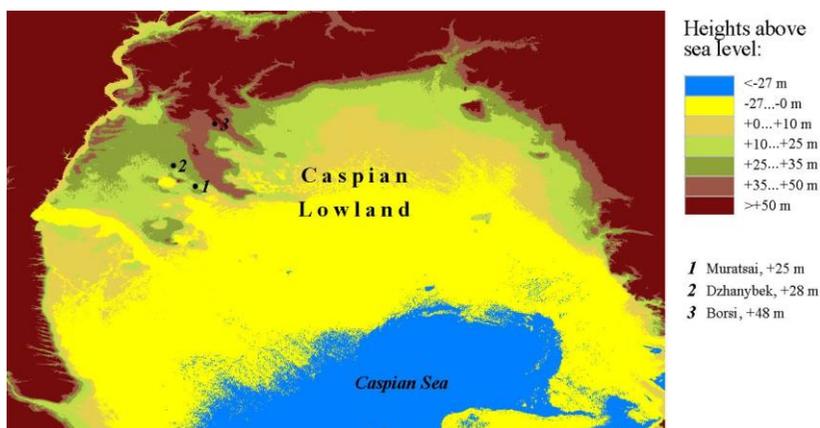


Fig. 2. The Caspian Lowland elevations based on the SRTM data (<http://srtm.csi.cgiar.org/>) corrected for 2 m to match the Russian (Pulkovo) datum.

are as follows: a high concentration of sodium sulphate starting from the bottom of the solonetzic B horizons and deeper, a loose consistency the saline C horizons with an abundance of “sand-like” salt aggregates within a depth range from 30 to 120 cm and a prevalence of coarse silt in the particle-size distribution of the parent rock. The properties of solonetz complexes within the Muratsai and Borsi sites have been revealed very recently ([Konyushkova and Abaturov, 2016](#)).

It should be mentioned that solonchakous Solonetztes at Muratsai and Borsi (with sodium-chloride and sodium-sulphate-chloride salinization, respectively) are both characterized by a high density of saline horizons and a prevalence of fine sand among coarse fractions of particle-size composition (in Borsi), whereas those fractions in similar soils at Dzhanybek are dominated by coarse silt.

Micromorphological samples were taken by us from soil trenches and pits. There were 2–3 replications of thin sections for each diagnostic soil horizon and each individual morphon of solonetzic aggregates. The thin sections were made using a Geoptic resin (with a refractive index $n = 1.534$) and air-drying treatment by M.A. Lebedev in the laboratory of V.V. Dokuchaev Soil Science Institute.

RESULTS AND DISCUSSION

The micromorphological analysis of solonetz samples from the Dzhanybek site allowed revealing more detail about the trends of changes in main fabric elements depending on microtopographic positions of soils. Common and individual micromorphological characteristics of different varieties of light-coloured Epialic Solonetz were revealed.

Fabrics of the surface horizons (Fig. 3). The typical characteristics of fabrics of the uppermost horizons of soils studied include a low content of clay particles and platy-lenticular microstructure and/or lamination by the size of particles within a massive structure (Fig. 3a–3c).

In a sequence from crust-like to deep solonetz varieties (according to [Rode and Polsky, 1961](#); [Field guide..., 2008](#), see Table) there are increasing contents of strongly decayed plant roots, biogenic aggregates and humus. Some features of eluviation (leaching) and surface gleying are found in meadow chestnut soils.

The crust-like and shallow solonetztes at all the three sites (Dzhanybek, Borsi and Muratsai) have the SEL surface horizon. The

upper vesicular crust micro-horizon is characterized by a massive structure with numerous rounded vesicle-like pores, a predominance of brown disperse humus micromorphs, an abundance of small iron-humus concentrations and a frequent occurrence of biogenic matter derived presumably from algae.

Along with general microfeatures, there also are site-specific microfeatures in the surface horizons of the soils studied. In Dzhyanybek's crusty solonchaks, there are specific fine-silty skeletons around vesicular pores (in the upper part) and microplates (in the lower part of the surface horizon) and abundant small iron-humus nodules. Muratsai's crusty solonchaks are characterized by currently active accumulation of fine silt within vesicular pores (Fig. 3b). Similar soils at Borsi contain intercalations (laminae) of fine organic-ferruginous-clay particles and pure fine silt (Fig. 3c). The matrix of all these surface horizons consists of compacted silt with occasional inclusions of charcoal, weakly decomposed organic matter and humus in form of a pigment.

Only in Dzhyanybek's crusty solonchaks the SEL horizon is subdivided into vesicular crust and laminated undercrust with a very gradual transition in-between, whereas in similar soils at Muratsai and Borsi such subdivision is not yet developed. The latter is probably indicative of relatively younger ages of the SEL horizons at Muratsai and Borsi, which are being formed with continuous accumulation of particles, which precipitate from suspensions and/or have aeolian origin, under conditions of non-percolative water regime.

The medium and shallow solonchaks of the Dzhyanybek site (6 soil pits) are characterized by the presence of bleached lenses and abundant plant debris within the surface part and platy and thin lens-like aggregates with dark humus-clay cap-like coating within the bottom part of the surface horizon (Fig. 3a). There is a general tendency for better defined shapes of isolated platy and thin lens-like aggregates at the Dzhyanybek site as compared to those at Muratsai and Borsi sites.

Some of the medium and shallow solonchaks have effervescent surface horizons due to accumulations of calcareous and saline substances near ground squirrel burrows. There are "sand-like" salt aggregates in the saline C horizons of soils from the Dzhyanybek site that are the micro-features of lateral movement of saline solutions along the slope gradient.

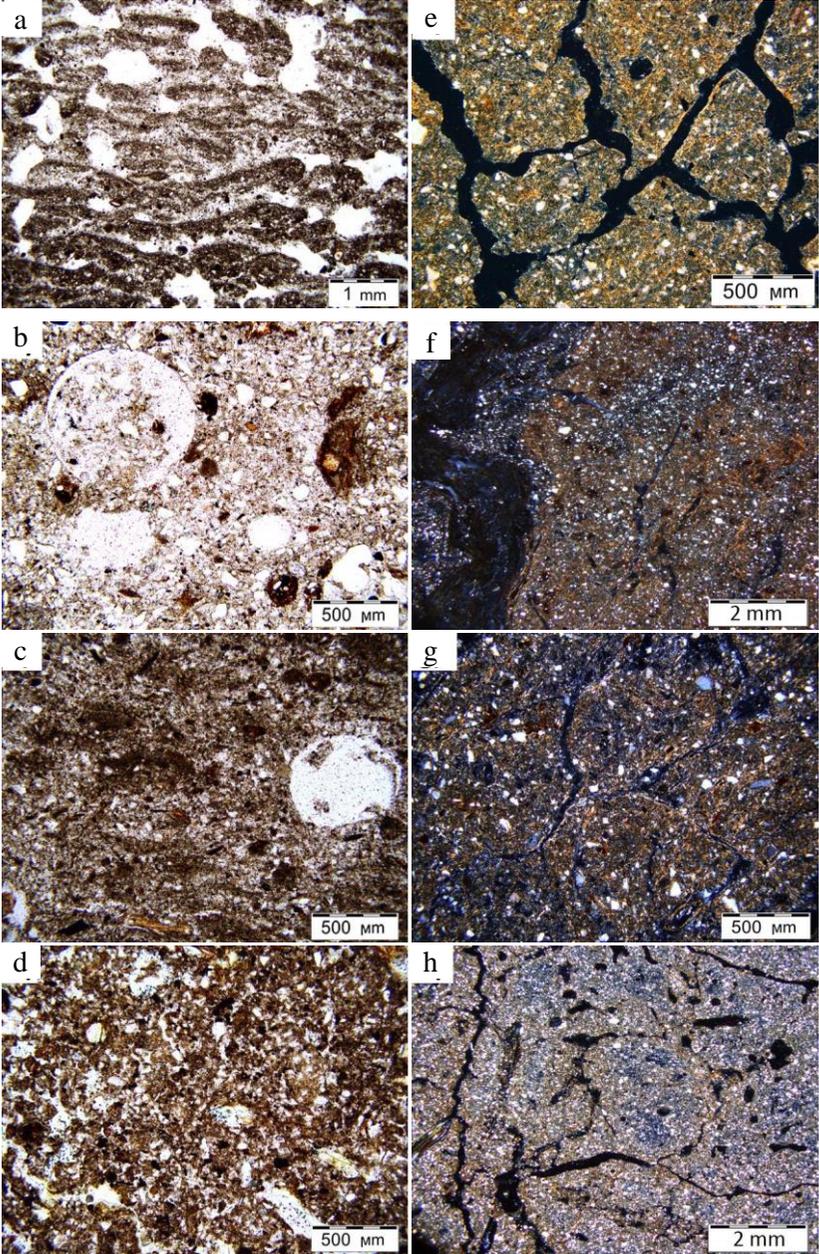


Fig. 3. a–d – Fabrics of the surface horizons of soils (PPL): a – lenticular microstructure with clay coatings on upper faces (shallow solonetz; pit 7M-02; SEL horizon; 0–7 cm; Dzhanybek site), b – vesicular microstructure with thick aeolian accumulations inside rounded vesicular pores, small ferruginous nodules (shallow solonetz; pit 3K-5; SEL horizon; 0–4(5) cm; Muratsai site); c – vesicular microstructure with low content of aeolian particles within vesicular pores, laminated accumulations of organic-clay particles precipitated from suspensions, small ferruginous nodules (shallow solonetz; pit 3K-2; SEL horizon; 0–5 cm; Borsi site); d – spongy microstructure, micro-clods of organic-clayey material, fine debris of plants (meadow chestnut soil; pit 915; AY horizon; 0–10 cm; Dzhanybek site).

e–h – Fabrics of the middle horizons of soils (XPL): e – angular blocky microstructure, high optical orientation of clay, thin clay coatings (shallow solonetz; pit 7M-02; BSN horizon; 14–20 cm; Dzhanybek site); f – high degree of microzonality: aggregates with highly-oriented clay and coatings prevail, spaces between them are occupied by infillings consisting of silty material of the BSN horizon and pore channels with plant roots (shallow solonetz; pit 3K-5; BSN horizon; 4(5)–16 cm; Muratsai site); g – rounded clay-rich aggregates with clay coatings and hypocoatings (shallow solonetz; pit 3K-2; BSN horizon; 5–16 cm; Borsi site); h – highly aggregated material with a high concentration of clay hypocoatings at the periphery of aggregates (meadow chestnut soil; pit 915; BMK horizon; 45–60 cm; Dzhanybek site).

The deep solonetz are characterized by clear differentiation of micro-features within their upper layer, where the AJel–AJ micro-profile is formed. The AJel horizon consists of fine-flaky light-grey material with abundant weakly decomposed plant debris. The AJ horizon is distinguished by a stronger humified material, spongy structure and active biogenic transformation of soil mass. Such deep variety of solonetz was called “steppefying” (“ostepnyayushchiysya”) by [Rode and Polsky \(1961\)](#).

The light-coloured chestnut soils are characterized by a higher content of humus and more active biogenic processes resulting in prevalence of well-decomposed plant debris within the AJ horizon. The microstructure of light-coloured chestnut soils is indicative of a cryogenic transformation of cloddy clay-humus aggregates. Sometimes the latter become attached, in undisturbed form, to platy units resulting in peculiar dumbbell-shaped cryogenic aggregates ([Lebedeva and Gerasimova, 2009](#)). Similar aggregates, though less impregnated by humus, have been found in chestnut soil from the Muratsai site. Such

aggregates always contain various amounts of anisotropic clay that can be oriented around skeletal grains or in bands or represented by clay papules (fragments of coatings).

The humus horizons of deeply-desalinated soils under mixed grass-herb communities at Dzhanybek and Borsi sites have microfeatures characteristic of meadow chestnuts soils: granular-cloddy structure with a high porosity between aggregates, a high content of plant debris decomposed to different degrees and abundant coprolites of various sizes. However, the respective horizons at Muratsai have different microfeatures, which are characteristic of chestnut soils: cloddy-platy structure, a small amount of humus concentrations and occasional aggregates containing anisotropic clay (including clay papules). These microfeatures illustrate a low content of humus in soils of shallow microlows, which originate apparently from a recent local subsidence of areas formerly occupied by solonetz, with water redistribution over slightly uneven microtopography still remaining insignificant.

To sum up the results of studying the fabrics of the surface horizons, there are several changes revealed between those horizons of meadow chestnut, light-coloured chestnut and crusty solonetz, which are caused by (1) water regime differences and (2) contribution from zoogenic factor resulting in formation of peculiar solonetz varieties – effervescent at the surface or intensively leached along the channels made by soil fauna. Virgin crusty solonetz are characterized by stagnant water regime leading to the formation of the SEL horizon with the vesicular crust and layered undercrust typical for the most arid pedogenesis.

Fabrics of the B horizons (Fig. 3e–3h). The solonetzic B horizons, being morphologically similar at a macro-scale, are significantly different at a micro-scale. These differences are as follows: (1) the degree of development of illuviation coatings, (2) the degree of preservation of coating fragments (papules), (3) the character of optical orientation of plasma and (4) the content of humus within peds.

An active illuviation of humus and clay particles and the current development of humus and clay coatings on the surfaces of angular blocky aggregates is a micro-feature of the modern solonetz formation process observed in crusty and shallow solonetz of all the three sites (Fig. 3e–3g).

However, there also are micro-features of degradation of solonchic B horizons in all soils studied: an active biogenic disintegration of characteristic angular blocky aggregates and early stages of clay impoverishment at the edges of such aggregates (Fig. 3f). The other micromorphological features of the solonchic B horizon site observed earlier in shallow solonchics of the Dzhanibek site ([Lebedeva and Konyushkova, 2011](#)) have not been found in the present study.

The crusty solonchics of the Muratsai site are characterized by clay coatings as well as certain microzones on aggregate surfaces, where silty material of the surface horizons is assimilated, hence resulting in lighter texture of the solonchic B horizon (Fig. 3f). The crusty solonchics of the Borsi site with similar macrostructure are also characterized by micro-features of degradation of angular blocky aggregates, especially, within the alkaline upper part of the solonchic B horizon – there are rounded micro-aggregates with clay quasi-coatings. The solonchic aggregates typically contain numerous clay coatings (Fig. 3g). There are common micro-features indicative of former hydromorphic conditions found in samples from Muratsai and Borsi, but not Dzhanibek – numerous dendroidal Fe-Mn pedofeatures.

An intensive degradation of micro-features within the lower parts of solonchic B horizons under the impact of salts “eating” these horizons from underneath was observed earlier in medium solonchics in some parts of the Dzhanibek site ([Lebedeva and Gerasimova, 2009](#)). However, medium solonchics in other parts of the Dzhanibek site don’t bear such degraded micro-features in solonchic B horizons. Instead, there are rounded aggregates with compacted peripheral material due to the presence of clay hypo-coatings, which are indicative of a much weaker degradation trend. The differences in degradation intensities are probably caused by different intensities and trends of salinization-desalinization processes depending on the proximity of soils to ground squirrel burrows and/or swell phenomena causing changes in microtopographic features above the degrading solonchic horizon with “sand-like” structure.

The deep solonchics contain abundant roots within vertical pores-fissures and numerous silty infillings made up of material from the surface horizons. These features are indicative of the BSN horizon degradation leading to highly contrasting fabrics – solonchic aggregates of different sizes with diffuse boundaries are incorporated into

silty material with a low content of clay. As was shown above, micro-features of biological degradation are also present within crusty solonetztes of Muratsai and Borsi – an increased number of plant roots at different stages of decomposition with silt pockets in the tissues.

The deep solonetztes of the Dzhanybek site, with salts leached to a significant depth, are characterized by a highly heterogeneous fabric within the lower part of the B horizon due to clay and iron impoverishment at the periphery of solonetzic aggregates and splitting of these aggregates by growing salt crystals. The micro-features of these processes have probably been formed at different times: clay and iron impoverishment at the aggregate periphery occurs during an intensive leaching period, while salt crystals between the aggregates originate from rising saline solutions.

In the calcareous solonetz, the BSN horizon structure is completely destroyed. The former aggregates are represented by diffuse shapes, yet with preserved clay orientation around skeletal grains.

The fabrics of the BMK and BM horizons of practically all light chestnut soils with different degrees of alkalization (manifested either chemically or macromorphologically) are characterized by microzones and/or microaggregates with increased optical orientation of clay (around skeletal grains or aggregate, Fig. 3h) and weakly anisotropic humus-clay plasma. The CAT and Cca horizons are characterized by a gradual increase in density at the aggregate periphery due to the presence of hypo-coatings. However, there are deep (below 100 cm) saline C horizons within microhighs at the Dzhanybek site, which contain a peculiar porous and highly aggregated “sand-like” material (Fig. 3d).

Remarkably, the Dzhanybek meadow chestnut soil within deep microlow, which during macro-scale field studies was designated as a “central image” (the most typical representative) of this soil type, has been reinterpreted at a micro-scale. Judging from the presence of humus-clay hypo-coatings on the aggregates within the BCA horizon that also occur in light-coloured solonetzic chestnut soils, it can be concluded that the soil under consideration has very recently evolved from a light-coloured solonetzic chestnut soil or even a deep solonetz.

The former alkalization features are still present in most leached soils of microlows at Borsi and Muratsai sites. There are individual zones or aggregates with banded orientation of clay in Borsi samples and flaky micro-features in Muratsai samples.

To sum up the results of studying the fabrics of the B horizons, there are micro-features of highly mobile finely dispersed particles of clayey, organic-clayey and ferruginous composition in all soils of the solonetz complexes studied (within microhighs, microslopes and microlows). There are widespread flaky, circum-skeletal, mosaic and banded types of orientation of the fine particles. Similar features of the solonetzic B horizons were earlier found in virgin and arable soils within large topographic depressions ([Verba et al., 2006](#); [Lebedeva and Sizemskaya, 2011](#)). A high degree of optical orientation of clay within the B horizons of the meadow chestnut soils is, apparently, a relic micro-feature of past alkalinization. It is generally recognized that there is no sodium in the exchange complex of modern soils. It is also known that the crusty and shallow solonchakous solonetztes as well as light-coloured solonetzic chestnut soils within the study area used to contain illuvial clay coatings on ped surfaces. Yet at the present time there are no such coatings in any soils of this area. Hypocoatings at the periphery of soil aggregates in light-coloured chestnut soils are still present or partly transformed into (fibrous)-flaky types of fabrics of finely dispersed matter ([Mermut, Pape, 1970](#)). At the same time the newly formed biogenic pores are beginning to be fill up with new humus infillings due to the in situ decomposition of roots.

Fabrics of the saline BC and C horizons (Fig. 4a–4h). The most significant differences between the study sites have been detected in the fabrics of the saline soil horizons. At the Dzhanlybek site, the saline horizons are distinguished by their loose consistency and highly aggregated “sand-like” structure ([Rode and Polsky, 1961](#)). At the micro-scale, the saline horizons of crusty and shallow solonetztes are characterized by the maximal number of gypsum pedofeatures – coatings, druses, dense and loose infillings (Fig. 4e–4g). The sizes and shapes of gypsum crystals from different depths are indicative of their different ages. The most recent gypsum pedofeatures are represented by gypsanas within biogenic pores and root channels.

The above-mentioned “sand-like” horizon with sodium sulphate salinity is responsible for swelling of solonchakous solonetztes as well as their surface subsidence due to dissolution of salts, the latter being one of the factors that cause formation of microlows ([Rode and Polsky, 1961](#)). The relationship between the compaction of such horizons (Fig. 4a–4c) and surface subsidence has been confirmed by the recent

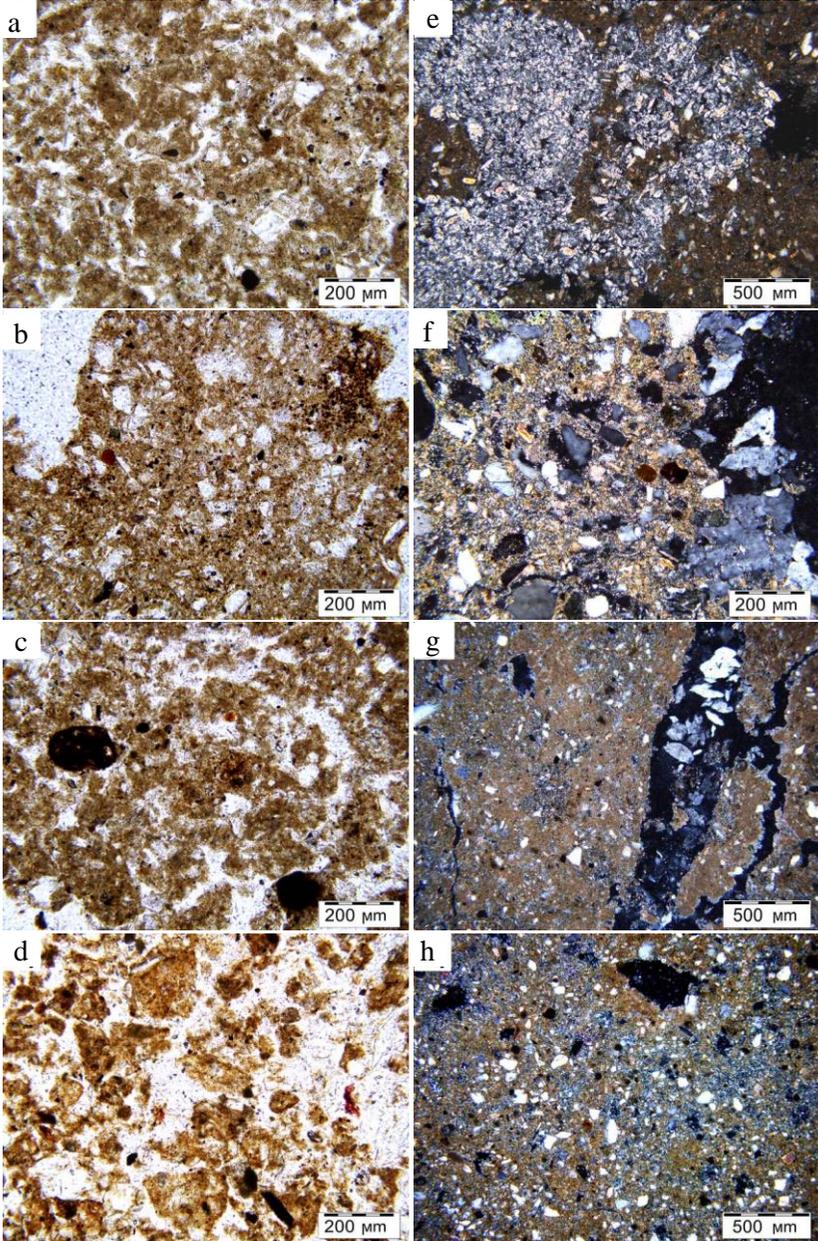


Fig. 4. a–d – Fabrics of the lower horizons of soils (PPL): a – melted and amalgamated “sand-like” salt aggregates, small particles of charcoal (shallow solonetz; pit 7M-02; BCAs,cs horizon; 40-45 cm; Dzhanybek site); b – compacted clayey-calcareous-silty material, a colony of Fe-bacteria (shallow solonetz; pit 3K-5; BCAs,cs horizon; 36-45 cm; Muratsai site); c – melted and amalgamated “sand-like” salt aggregates, dense Fe-nodules (shallow solonetz; pit 3K-2; BCAs,cs horizon; 40-45 cm; Borsi site); d – very porous material with “sand-like” salt aggregates, salt druses in pores between aggregates, fragments of charred plant tissues (shallow solonetz; pit 02-15; BCAs,cs horizon; 30-50 cm; Dzhanybek site)

e–h – Fabrics of the parent rocks and overlying transitional soil horizons (XPL): e – dense infillings consisting of small clusters of gypsum crystals inside pores (shallow solonetz; pit 7M-02; Cca,s horizon; 100–145 cm; Dzhanybek site); f – gypsum coating on aggregate surface (shallow solonetz; pit 3K-5; Cca,s horizon; 80–85 cm; Muratsai site); g – clusters of gypsum crystals inside pore channels among compact highly calcareous material (shallow solonetz; pit 3K-2; Cca,s horizon; 80–85 cm; Borsi site); h – rare micrite coatings around pores, microzonal distribution of fine sand and finely dispersed particles (meadow chestnut soil; pit 915; Cca horizon; 100–110 cm; Dzhanybek site).

study and a microtopographic survey (using a dumpy level) of solonchakous solonetztes ([Konyushkova and Abaturov, 2016](#)). At the micromorphological scale, the formerly loose “sand-like” saline horizons (Fig. 4d) are characterized by decreasing pore spaces between rounded calcareous-silicate-salt aggregates (Fig. 4a) in the course of recent evolution of virgin Epialic Solonetztes under conditions of a rising groundwater table during the last 50 years ([Lebedeva and Konyushkova, 2016](#)). The modern micromorphological techniques have allowed detecting single “sand-like” aggregates within compacted calcareous silty clay material of the saline horizon of shallow solonetz of the Dzhanybek site. These micro-features indicate the development of subsidence, being further confirmed by a very light colour and gley features of this horizon observed in field.

The saline horizons of solonetztes of the Muratsai and Borsi sites consist of more compact calcareous clay material with more developed calcareous coatings, hypo-coatings and impregnations (Fig. 4b, 4c). There are micro-features of ferrugination around the calcareous nodules and noduls (Fig. 4c), which are unlikely to be connected with the modern gleying, because the groundwater table is deeper than 5 m. The

saline horizons of Muratsai are characterized by higher porosity and sand content (but still less porous/loose than those of Dzhanybek) as well as traces biological activity at a depth of more than 120 cm.

CONCLUSION

The study of soil horizons and morphons (in both trenches and individual pits) has revealed that the closest relationship between macro- and micromorphological features is developed only within the surface horizons, which show the clearest diagnostic features of humus accumulation and biogenic structuring processes. The intensity of these processes increases in soils of all microlows (compared to soils on level microtopography), but reaches its maximum in the deepest microlows. A less close relationship between macro- and micromorphological features has been found in the middle horizons of all soils within solonetz complexes of the study sites. Differences in fabrics of the BSN horizons of the same varieties of solonetz and the middle horizons of the same types of other soils of different study sites (Dzhanybek, Muratsai and Borsi) are indicative of the variability of those soils and, therefore, the highly-dynamic soil cover of studied semidesert solonetz complexes within close-drainage plains of different ages. Taking into account the evolutionary instability of semidesert solonetz complexes (according to [Ivanova and Fridland, 1958](#)), it is suggested that the studied soils comprise a combination of features of different (modern and relic) stages of their cyclic development.

Light-coloured chestnut soils, which occupy microslopes of deep microlows at the Dzhanybek site as well as shallow microlows at the Muratsai site, are characterized by highly oriented clay inside peds and also illuvial clay coatings that are typical of crust-like and shallow solonetz at all study sites. Hence, it can be concluded that different degrees of modern micromorphological salinity of light-coloured chestnut soils is unrelated to their microtopographic positions, but connected to a large extent with their recent solonetzic stage of pedogenesis.

Likewise, meadow chestnut (chernozem-like) soils occupying deep microlows have microfeatures of clay migration that, in our opinion, are indicative of the former solonetzic processes. Therefore, the character and degree of optical orientation of clay plasma in textural horizons are stable microfeatures that can be used in palaeogeographic reconstructions.

Gleying microfeatures, which were undetectable at a macro-scale, have been revealed in saline horizons of solonchaks at all the three sites. The depth of occurrence of dendroidal iron-manganese pedofeatures is indicative of the current rising of the groundwater table, which is especially high at the Dzhanybek site (in the lower part of the BSN horizon, at a depth of about 30 cm). It can be suggested that microstructures of solonchak or middle horizons of light-coloured chestnut soils and meadow chestnut soils undergo reorganization within a few decades, while finely dispersed matrix is more inertial and retains its high optical orientation in middle horizons of all soils studied.

We suggest that the analysis of modifications in soil microfeatures should be more regularly carried out when studying the dynamics of microtopography. To achieve this, microtopographic surveys (using a leveling instrument, e.g., dumpy level) along trenches should be carried out to assess the spatial variability of soil microfeatures.

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