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Changes in the fabric of a solonetz under irrigation in Trans-Volga region

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The sampling was done on a steppe and meadow-steppe solonetz on the territory of the Kislovsk Irrigation Project in the northern Pre-Caspian Lowland [2]. Levelling before irrigation only acted to increase the non-uniformity of soil cover and worsen the properties of all the soils of the Trans-Volga steppe complex. The greatest harm from levelling was to a solonetz occupying elevated elements of relief.

The samples were subjected to micromorphological analysis. The sections were prepared from oriented samples with an intact structure [1, 3].

THE MICROMORPHOLOGY OF A STEPPE SOLONETZ

The virgin steppe solonetz under study is generally low in humus in the upper horizon (some 2%), and has an exchange capacity from 20 to 22 me in the humus horizon and from 25 to 28 me in solonetz and sub-solonetz horizons. Exchange-sodium content makes up 4-10% of the exchange capacity in the humus horizon and 10-15% (sometimes 20%) in the solonetz and sub-solonetz horizons. Watersoluble salts are absent from upper portions of profile.

The fabric of the solonetz-overlying horizon is non-uniform, with portions of aggregated and peptized plasma alternating. Aggregated plasma portions are fewer in number. The portions with peptized plasma betray laminarity of fabric. Clay matter has a flecked orientation pattern and occurs as cutans of optically oriented clay. Plasmic fabric is insepic (Brewer). Some portions are rather poor in plasmic fabric. Pores mainly occur as joint planes parallel to soil surface. Ferric nodules and single rounded ferric concretions are met with.

The solonetz horizon (10-26 cm deep) is structureless and almost perfectly compact. Porosity drops to 10%, pores are rounded (vughs and vesicles). Plasma is completely peptized and highly mobile, and has a striated orientation pattern occurring as cutans along pores. Fabric is mo-vosepic. The horizon abounds in dark organo-argillans from upper layers and its whole horizon is more sharply ferruginized. As a whole, the horizon is more sharply argillized as compared with the solonetz-overlying horizon, and extremely non-uniform as regards argillization having many microalluvial spots.

The sub-solonetz horizon (26-43 cm deep) is also structureless, yet with a more uniform fabric, compact, porosity below 10%, pores mostly rounded or appear as clearly defined skew planes. Plasma is peptized and occurs as cutans and striated separations. Fabric may be described as skel-mosepic.

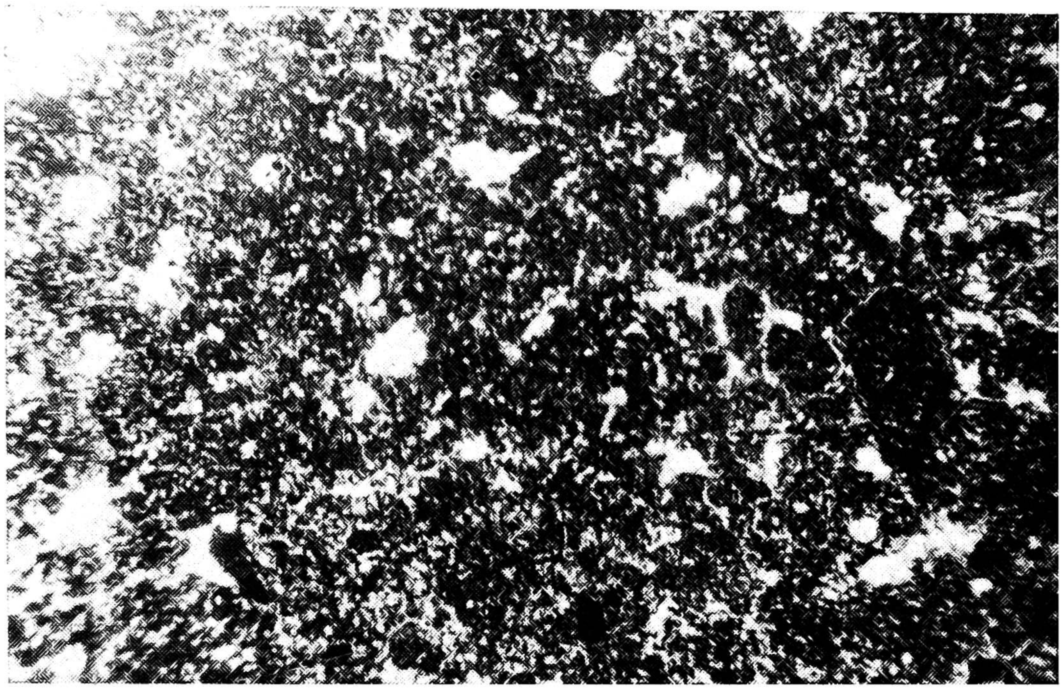

Fig. 1. Captions fabric of the solonetz horizon of a steppe non-irrigated solonetz. Thin section in plain light 30×.

Next comes a carbonate horizon (50-70 cm deep). Uniform, plasma aggregated with carbonates, fabric compact, porosity some 15%, micro-crystal carbonates accumulating along skew planes. Plasmic fabric crystic.

Under a microscope, virgin solonetz samples show little or no structure, sharply peptized plasmic fabric in the upper profile and appreciable illuviation down profile.

THE MICROMORPHOLOGY OF A MEADOW-STEPPE SOLONETZ

Solonetz-overlying and solonetz horizons are non-saline, maximum salinity occurring in sub-solonetz horizons with sodium sulphate prevailing. The upper horizon contains some 2% of humus, its content gradually decreasing down profile. A meadow-steppe solonetz is somewhat lower in exchange capacity than a steppe solonetz. Exchange sodium is contained in the former in the same amount as in the latter.

However, the fabric of a meadow-steppe solonetz appreciably differs from that of a steppe solonetz (Yarilova). In a virgin meadow-steppe solonetz, the structure of the solonetz-overlying humus horizon (10 cm deep) is usually foliated, horizontal layers 0.5 to 0.7 mm thick are divided by thin horizontal joint planes, plasma is partly coagulated, while most of plasma peptized. The plasmic fabric of the solonetz-overlying horizon may be described (according to Brewer) as partly isotic and partly asepic. Along skew planes, vosepic fabric areas occur. Scattered over the humus horizon are ferric nodules, rare concretions thickly coloured with humus substance and plasma concentrations.

The solonetz horizon (approximately 15-20 cm deep) is more compact. Its clay-mineral mass is divided by skew planes into angular peds, approximately 1.5 cm in size. Plasma inside aggregates has a mo-vosepic fabric. Porosity is as low as 10%, the pores are mostly rounded (vesicles).

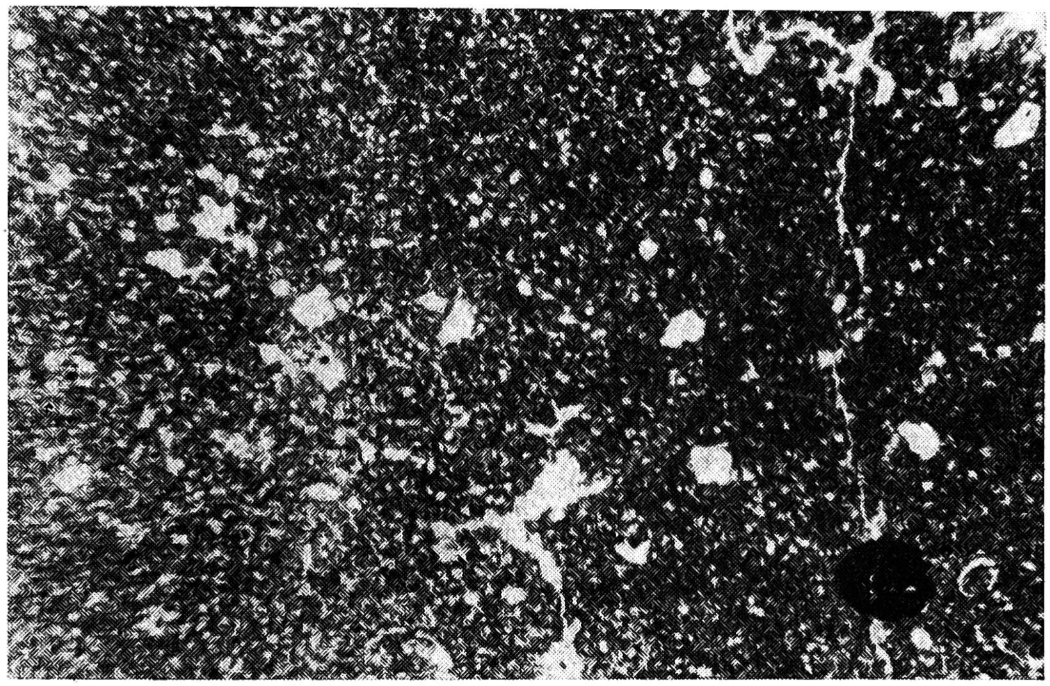

Fig. 2. Fabric of the solonetz horizon of a steppe solonetz after 3 years' irrigation. Thin section in plain light 30×.

The solonetz-underlying saline horizon (some 40 cm thick) is called pseudo-sand horizon because of its being highly aggregated.

Structural peds (0.1-0.3 mm in diameter) are very loosely packed. Porosity exceeds 30%, most of the pores being craze (vughs and skew planes). Plasma is coagulated. Its fabric may be described as crystic.

In the second solonetz-underlying horizon, clay mineral mass is somewhat less aggregated, while at lower depths, clay-carbonate plasma is not aggregated at all. Many accumulations of gypsum occur in the lower portions of profile.

Horizon C has compact structure, and a porosity lower than 10%, its clay-carbonate plasma is light-brown in colour with druses of fine-granular carbonates. There are sporadically occurring argillans of oriented clay.

Upon levelling, the solonetz-overlying horizon is sliced off (and sometimes the solonetz horizon) and the solonetz horizon (and sometimes the solonetz-underlying horizon) comes out into the surface to become arable.

An air- and water-tight foliated crust 10-15 mm thick forms over the arable solonetz horizon. On ploughing, the solonetz horizon gets broken into big lumps, plasma being removed from their surface. The clay-mineral mass inside the lumps is not aggregated, the porosity is lower then 10% and the plasma completely peptized. The plasmic fabric of the arable layer is mosepic.

The amount of argillans and organo-argillans (of optically oriented clay) sharply increases in the sub-arable horizon. Recent, fresh, light-coloured argillans are clearly different from old dark ones to have been formed before irrigation.

Thus on initial stages of irrigation in a solonetz with the humus horizon removed, micro-aggregates are almost completely destroyed, clay gets much less coagulated and the entire clay-mineral mass peptized. Plasma becomes much more mobile and porosity drops below 5%. A very compact clay crust forms on the surface of the arable solonetz horizon. As result of irrigation, the difference of fabric between steppe and meadow-steppe solonetzes is reduced. The increased peptization of plasma of a solonetz deprived of humus horizons may be reversed only by conditioning the soil with aggregation-promoting agents.

The author of this paper studied effects from gypsuming of a steppe solonetz deprived of upper horizons. Gypsum was applied in a finely grained form before ploughing in an amount of 15 tons per hectare. Three years after gypsuming, the compact lumpy arable solonetz horizon became loose and fine-granular. The clay crust failed to form. The compact clay mineral mass became aggregated (aggregates 1.5-2 mm in diameter).

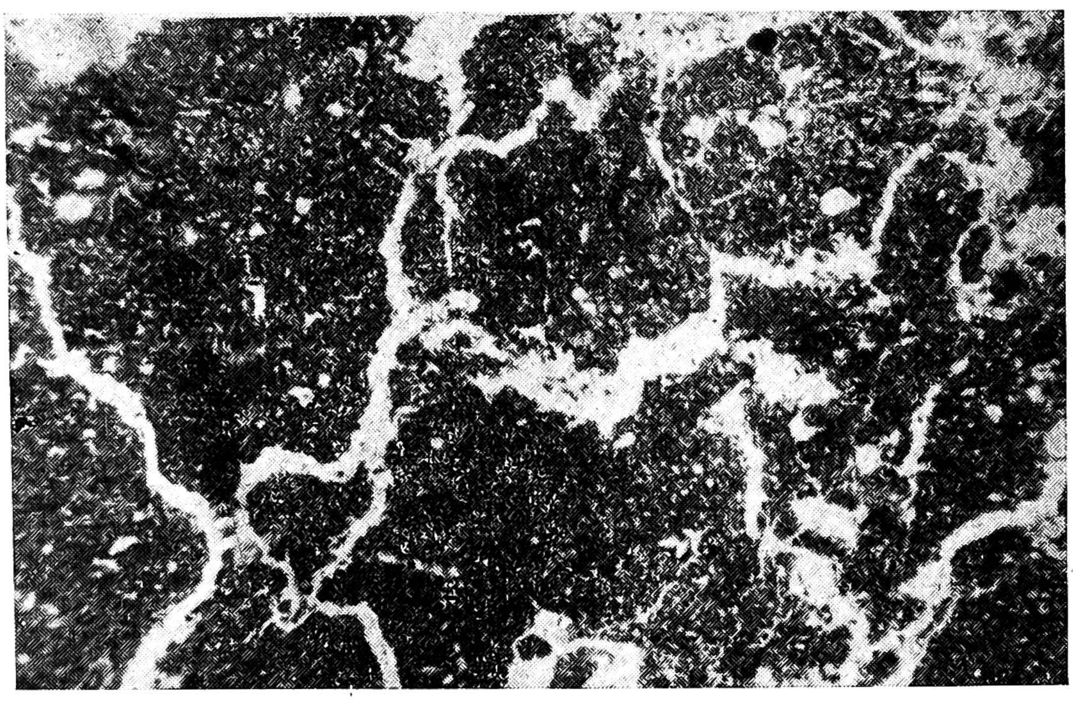

Fig. 3. Gypsum-aggregated solonetz horizon, depth 0-10 cm. Thin section in plain light 30×.

Its microporosity changed from virtually zero to 25-30%. Its pores became big and craze (vughs and skew planes). Plasma inside aggregates retains peptizity while getting coagulated on the surface of aggregates. It is noteworthy that the surface of newly formed aggregates are confined to clay-free micro-areas of the solonetz horizon. It is along these areas that this swollen and compact horizon gets ruptured. As the solonetz mass gets coagulated, a whole number of intermediate zones from the state

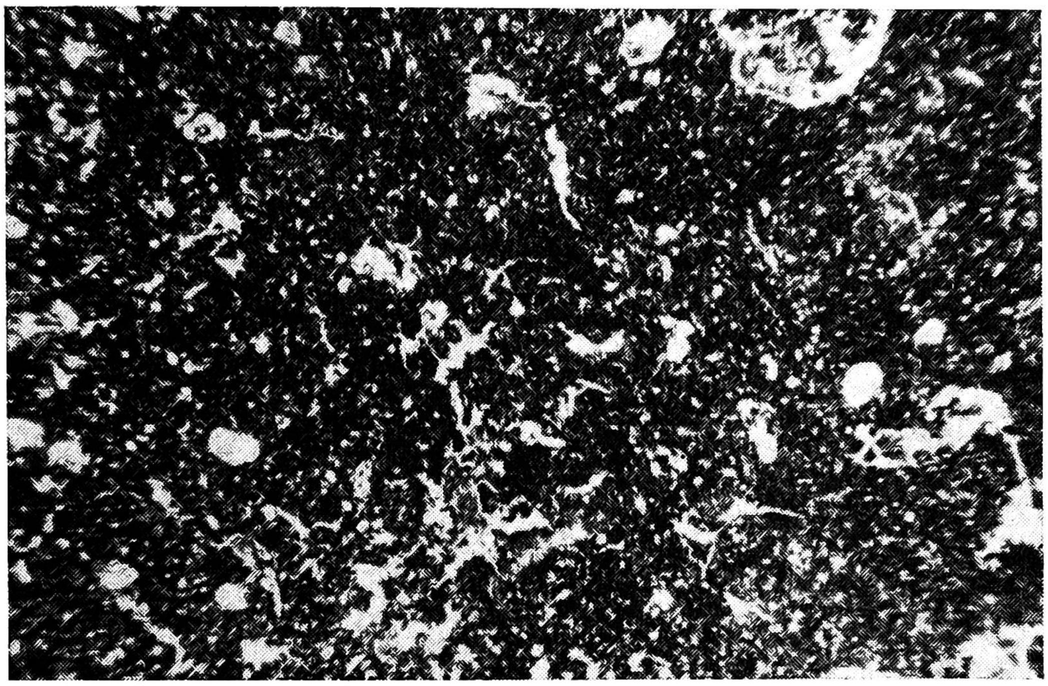

Fig. 4. Fabric of the solonetz horizon of a non-irrigated meadowsteppe solonetz. Thin section in plain light 30×.

of peptization of that of aggregation meet the eye. It is especially significant that argillans and organo-argillans develop cracks and get translucent gradually loosing anisotropicity while retaining concentric structure.

The coagulating effect of gypsuming extends to a depth of 40-50 cm down profile. At a depth of 30-50 cm, no small-sized aggregates are formed, but just as in the upper 30 cm deep layer, porosity increases to 12-15%. The pores are thin and craze dividing the soil mass into more sizable peds 4-5 mm in diameter.

Its humus and solonetz horizons having been removed, the given solonetz starts changing upon irrigation very fast and more sharply as compared with changes in other solonetz varieties occurring upon levelling. The upper arable horizon, which was formerly a saline pseudosand horizon with a well aggregated clay mineral mass and a porosity exceeding 35%, has now a different fabric: its porosity drops to 15-20% and, even though it retains its highly aggregated clay mineral mass, the packing of aggregates becomes more compact. Structural aggregates get rounded on the periphery, while first-order aggregates (0.08-0.12 mm in diameter) inside the structural aggregates retain their more pronounced outlines. The rounding of the bigger aggregates may be attributed to the

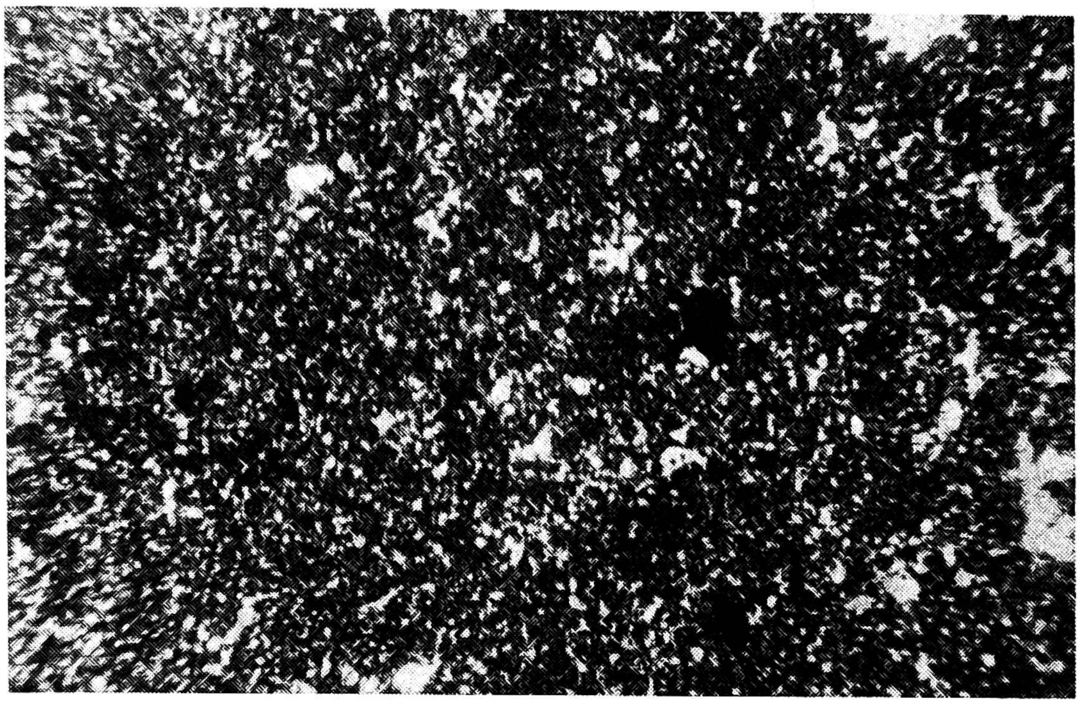

Fig. 5. Fabric of the solonetz horizon of a meadow-steppe solonetz after 3 years' irrigation. Thin section in plain light 30×.

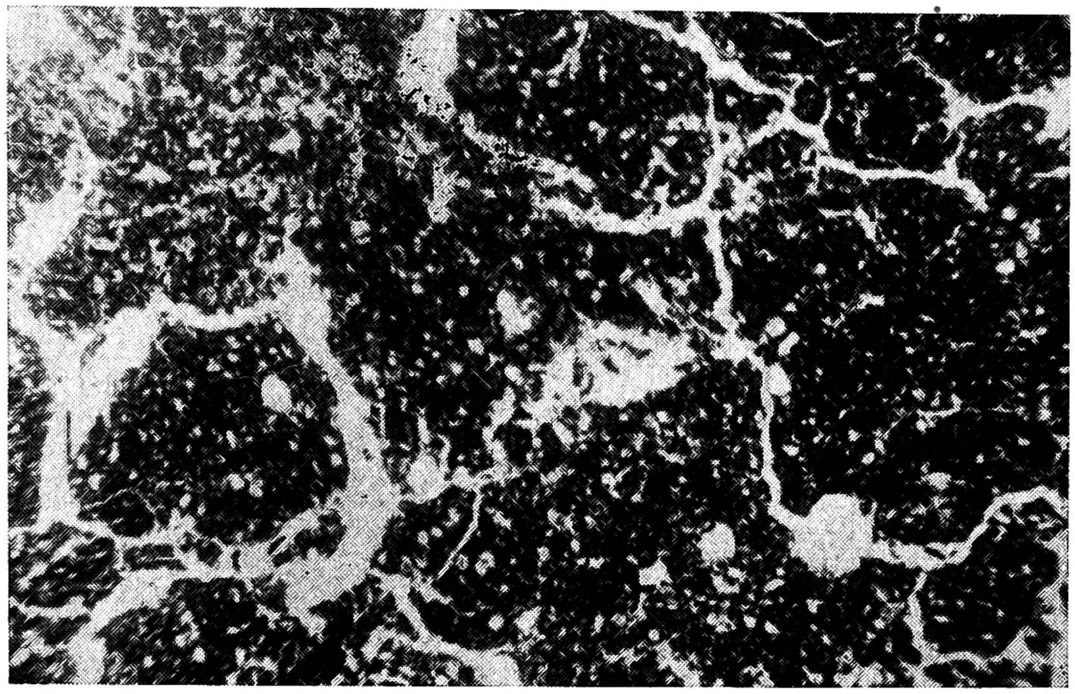

Fig. 6. Fabric of the pseudo-sand horizon of a meadow-steppe solonetz. Thin section in plain light 30×.

leaching of salts which, though impregnating the entire plasma, tend to concentrate on the surfaces of the bigger aggregates. On leaching the salts, the plasma retains its state of coagulation (crystic fabric). Thus, at the initial stages of desalinization, formerly salt-bearing horizons do not get alkalinized.

CONCLUSIONS

1. The study of irrigated solonetz, with humus horizon removed, provides grounds for statement that the removal of the humus horizon followed by irrigation gives rise to so adverse a fabric of the solonetz hori-

zon (the absence of any aggregation; the peptization of clay plasma; a reduction in porosity below 5% and crust-formation on the surface) as to preclude the development of a solonetz for cultivation by methods other than application of soil-conditioning agents.

2. The application of 15 tons of finely grained gypsum per hectare on the surface of the solonetz horizon of a steppe solonetz, its upper layer having been removed, quickly causes the solonetz horizon to acquire a new well-aggregated and porous fabric (its porosity growing from 5 to 25-30%). Besides, the surface crust completely disappears and the solonetz horizon becomes aggregated.

3. On removing the humus and solonetz horizons, a meadow-steppe solonetz (with its pseudo-sand horizon being stripped open) can be developed without any special reclamative measures, since the clay plasma remains highly aggregated after the salts are leached out, even though the packing of aggregates gets more compact and porosity reduced.

4. In the solonetz of the Trans-Volga region porosity under 10% was responsible for the adverse water-physical constants of the soil.

5. A sharply defined anisotropicity in the fabric of a solonetz (especially porosity) has to be considered while determining the optimum water-physical constants with a view to irrigation.

SUMMARY

1. The investigations have been carried out on a drainless salt-affected plain under a complex vegetative cover (the northern part of the Pre-Caspian Lowland). The steppe and meadow-steppe soil complexes include here solonetz soils, chestnut soils and dark-coloured soils of padinas. Levelling, which preceded irrigation, increased mottling of the soil cover and deteriorated the agronomic and water-physical properties of the solonetz soils.

2. The steppe solonetz soils with a removed humus horizon (irrigated without preliminary reclamation) as well as levelled to various depth the meadow-steppe solonetz soils have been subjected to micromorphological study.

3. The steppe solonetz soils with a removed humus horizon and bared solonetzic one, are characterized by an almost complete destruction of microaggregates; transition of the whole of the fine-grained part of soil into a peptized status; a higher mobility of clayey matter and iron; an increased compactness and decreased porosity.

An air and moisture impermeable stratified crust is formed on the surface of the ploughed irrigated solonetzic horizon. Reclamation of such soils requires application of soil structurizing amendments.

4. When gypsum is applied at a rate of 10-15 tons per ha, the peptized clayey-mineral mass of the solonetzic horizons is aggregated into simple

structural separates 1-2 mm in size. A sharp increase in porosity (from 5-10% to 35-40%) is also observed.

However, the intraaggregate porosity remains low and peptization of the clayey matter inside the new structural separates is preserved. Gypsum actively affects the solonetz profile down to a depth of 35-40 cm.

5. When meadow-steppe solonetz soils with a removed humus horizon and bared solonetzic horizon are irrigated, a complete peptization of the clayey matter and its intensive leaching down the profile into the salt-affected horizons are observed. Intensive crust formation and extremely low porosity make this horizon practically barren. Mixing of the bared solonetzic horizon with the underlying solonchakous horizon brings about coagulation and lowers mobility of the clayey matter; increases porosity and aggregation of the clayey-mineral mass.

6. Irrigation of the meadow-steppe solonetz soils with a removed humus and solonetzic horizons (when the pseudosandy salt-affected horizon comes to the surface) brings about their self-reclamation.

Soluble salts are leached from the pseudosandy horizon by the first norms of irrigation waters. Lowering of porosity (from 25-30% to 10-15%) and a more compact arrangement of aggregates are observed but deterioration of microaggregation does not take place.

Both chemical and micromorphological methods fail to state alkalinity in the desalinized horizons.

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