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Pleistocene soils of the Azov Lowland, Ukraine

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Abstract. With the aim to reconstruct the Pleistocene soils in Azov Lowland (geological sections near the villages of Bezimenne and Melekine Donetsk region), we carried out palaeopedological research. The Paleopedological method was used, which consisted with a detailed analysis of the morphological (color, structure, granulometric composition,

humidity, composition, neoplasms, inclusion, transition between horizons, border) and micromorphological (skeleton, plasma, color, aggregation, porosity, organic and clay parts, mineral skeleton, tumors, microstructure) features. Paleopedological studies of Pleistocene soils have allowed to determine the types of these deposits and to follow the dynamics of changes in soil conditions: - warm-temperate with signs and close to subtropical, when formed reddish cinnamon (kr_{b1}), reddish brown (kr_{b2}), cinnamonish-brown (sh_{b1}), reddish cinnamon (sh_{b2}), dark-colour (meadow reddish cinnamon) merged ($mrb2 + mr_{b1}$), reddish cinnamon, brownish, fused saline soils (mr_3) Kryzhanivka, Shyrokyno and Martonosha soils, which are distinguished by reddish shades of coloring of the profiles, are the most ferruginous, clay, with a large number of nodules with concentration of organo-iron-clay material; - moderately-warm transition to subtropical – red-brown saline (lb_{b2}), dark-colour (brownish-cinnamonic) fused ($lb_{b2} + lb_{b1}$) heavy loam Lubny soils, with are less clayed, ferruginous and formed in meadow-steppe and steppe conditions (brownish-gray with cinnamonish shades of coloring profiles, the presence of moleholes, complex microaggregation); - moderately variable – humid close to subtropical – cinnamon and cinnamon saline (zv_{b1}), reddish-cinnamon saline (zv_{b2}), heavy loam Zavadiivka soils, which are a transitional variant to temperate climates, although some of the features of the lower Pleistocene soil formation are retained (ferrugination, presence of segregated clusters organo-clay and clay materials, microortshteins); - moderately-warm equally humid – cinnamon-brown (kd_{b1}), ordinary chernozems (kd_{b2}), cinnamonish-gray saline (pl_{b1}), chernozem saline (pl_{b2}), brown steppe (pl_c), heavy and medium loam Kaydaky and Pryluky soils, characterized by the grayish shades of coloring of profiles, the presence of moleholes, carbonates, complex microaggregates, pores and are closest to modern soils; - moderately-warm subarid – cinnamonish-brown (vt_{b2}) heavy loam Vytachiv soils formed under the influence of turf (the presence of crust, carbonate, complex microaggregates) and brown-liked (cinnamonish-brown color of the profile, spatial structure of clays) of soil formation processes and have no analogues in modern soil cover; - moderately-continental and more arid (dry) – chernozems saline (df_{b2}), brown saline (df_c), desert-steppe fulvous (df_c), medium loam Dofinivka soils, with clear features of xeromorphism (low profile power, its carbonate, lack of signs of organo-mineral materials) replacing.

Key words: paleopedology, Pleistocene, palaeosol morpho-, and micromorphology.

Плейстоценові ґрунти Приазовської низовини території України

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Анотація. З метою реконструкції плейстоценових ґрунтів на території Приазовської низовини (геологічні розрізи біля сіл Безименне і Мелекіне Донецька область) нами були проведені палеопедологічні дослідження. При їх дослідженні був застосований палеопедологічний метод, що полягав у детальному аналізі їх морфологічних (забарвлення, структура, гранулометричний склад, вологість, складення, новоутворення, включення, перехід між горизонтами, межа) і мікроморфологічних (скелет, плазма, колір, агрегованість, пористість, органічна і глиниста частини, мінеральний скелет, новоутворення, мікроструктура) особливостей. Проведені палеопедологічні дослідження плейстоценових ґрунтів дозволили встановити типи цих відкладів та прослідкувати динаміку змін умов їх ґрунтоутворення: - тепло-помірних з ознаками і близьких до субтропічних, коли формувалися червонувато-коричневі (kr_{b1}), червонувато-бурі (kr_{b2}), коричнювато-бурі (sh_{b1}), червонувато-коричневі (sh_{b2}), темноколірні (лучно-червонувато-коричневі) злиті ($mr_{b2} + mr_{b1}$), червонувато-коричневі буруваті злиті солонцюваті (mr_3) крижанівські, широкинські і мартоносські ґрунти, які вирізняються червонуватими відтінками забарвлення профілів, є найбільш озалізненими, глинистими, із великою кількістю оодоподібних стяжінь органічно-залізо-глинистої речовини;

- помірно-теплих перехідних до субтропічних – червоно-бурі солонцюваті (lb_{b_2}), темноколірні (бурувато-коричневі) злиті ($lb_{b_2} + lb_{b_1}$) важкосуглинкові лубенські ґрунти, є менш оглиненими, озалізненими і формувалися у лучно-степових і степових умовах (бурувато-сірі з коричнюватим відтінком забарвлення профілів, наявність кротовин, складна мікроагрегованість); - помірних змінно-вологих близьких до субтропічних – коричневі і коричневі солонцюваті (zv_{b_1}), червонувато-коричневі солонцюваті (zv_{b_2}) важкосуглинкові завадівські ґрунти, які представляють собою перехідний варіант до ґрунтів помірного клімату, хоча зберігають деякі риси нижньоплейстоценового ґрунтоутворення (озалізненість, наявність сегрегаційних скупчень органо-глинистої і глинистої речовини, мікроорштейнів); - помірно-теплих рівномірно вологих – коричнювато-бурі (kd_{b_1}), чорноземи звичайні (kd_{b_2}), коричнювато-сірі солонцюваті (pl_{b_1}), чорноземи солонцюваті (pl_{b_2}), бурі степові (pl_c) важко- і середньосуглинкові кайдацькі і прилуцькі ґрунти, які характеризуються сіруватими відтінками забарвлення профілів, наявністю кротовин, карбонатів, складних мікроагрегатів, пор і є найбільш близькими до сучасних ґрунтів; - помірно-теплих субаридних – коричнювато-бурі (vt_{b_2}) важкосуглинкові витачівські ґрунти, що формувалися під впливом дернового (наявність кротовин, карбонатність, складна мікроагрегованість) і буроземоподібного (коричнювато-буре забарвлення профілю, лукувата структура глин) ґрунтоутворювального процесів і не мають аналогів у сучасному ґрунтовому покриві; - помірно-континентальних і аридніших (сухих) – чорноземи солонцюваті (df_{b_2}), бурі солонцюваті (df_c), бурі пустельно-степові (df_c) середньосуглинкові дофінівські ґрунти, з чіткими рисами ксероморфізму (мала потужність профілю, його карбонатність, відсутність ознак перерозподілу органо-мінеральних речовин).

Ключові слова: палеопедологія, плейстоцен, ґрунти, морфо-, мікроморфологія.

Introduction. The Pleistocene soils, which started to develop about 2.6 million years ago, are one of the most important indices for palaeogeographical reconstructions of this period. They are peculiar natural indicators, phenomena and «monuments» of the ancient natural conditions of the time of their formation. No wonder the fossil soils are considered as a kind of archaeological paleogeographic information. Paleopedology, the branch of paleogeography (the science about the ancient geographic sphere and the nature of the Earth's surface), which studies ancient (fossil) soils, deals with the study of fossil Holocene, Pleistocene, Pliocene and more ancient soils and deposits (Veklych e. a., 1979).

Prerequisite for conducting paleopedological studies of Pleistocene soils in the Azov Lowland is the presence on the Azov Sea of the outskirts of the Pleistocene and somewhere more ancient Neogene deposits. Since the Azov lowland is a stratotype region of the Pliocene-Pleistocene deposits in the southern part of Ukraine. Paleopedological investigations on this territory (sites near Mariupol, Shirokine village) were conducted by M.F. Veklych, N.O. Sirenko, Zh.M. Matviishyna (Veklych, 1968, 1982; Veklych, Sirenko, 1972; Veklych e. a., 1973) and later by the author (Karmazinenko, 2013, 2014, 2017).

Material and methods of research. In the study of Pleistocene soils in the Azov Lowland, a paleopedological method was used which based on the study of morphology (color, structure, granulometric composition, humidity, composition, neoplasm, inclusion, transition between horizons, boundaries) and micromorphological (skeleton, plasma, color, aggregate, porosity, organic and clay portions, mineral skeleton, neoplasms, microstructure) of the features of ancient deposits (Veklych e. a., 1979; Karmazinenko, 2010; Matviishyna, 1982).

In order to reconstruct the Pleistocene soils

in the Azov Lowland, the author carried out field paleopedological research of Pleistocene soils of Kryzhanivka (kr), Shyrokyno (sh), Martonosha (mr), Lubny (lb), Zavadiivka (zv), Kaydaky (kd), Pryluky (pl), Vytachiv (vt), Dofinivka (df) stratigraphic horizons (Veklych e. a., 1993; Gozhik e. a., 2012) of the villages of Bezimenne (5 clearings) and Melekine (7 clearings) of the Donetsk region. It should be noted that in order to clarify the genesis of the Pleistocene soils, we first used a micromorphological analysis (200 thin section with undisturbed structure were analyzed under a polarization microscope).

Results and their analysis. On the basis of the results of Paleopedological (morphological and micromorphological) studies of Pleistocene soils of Kryzhanivka (kr), Shyrokyno (sh), Martonosha (mr), Lubny (lb), Zavadiivka (zv), Kaydaky (kd), Pryluky (pl), Vytachiv (vt), the Dofinivka (df), stratigraphic horizons (Veklych e. a., 1993; Gozhik e. a., 2012), a change of paleogeographic conditions during the specified stages in the Azov lowlands was observed.

Kryzhanivka horizon (OIS – 53-41 (Veklych e. a., 1993; Gozhik e. a., 2012). Kryzhanivka age formation were studied near village Melekine. They represented by soils of climatic optimum: reddish-brown (kr_{b_2}) and reddish-cinnamon (kr_{b_1}). Characteristic features of their morpho- and microstructure are: reddish shades of coloration, ferrugination (studied soils, among all the studied are most ferruginous), clayed, in the microstructure the presence of segregation of clay and iron-clay material, impregnation of the plasma by microcrystalline calcite.

The upper reddish-brown soil of the climatic optimum (kr_{b_2}) in its microstructure reflects the signs of the processes of some transition to steppe of landscapes (the development of simple and complex microaggregates, intense penetration of plasma by microcrystalline calcite in the lower part of the

profile). Although, the presence of nodules with concentration of iron-clay material, microortshteins in soils is evidence of an alternating humid regime during their formation (Fig.1).

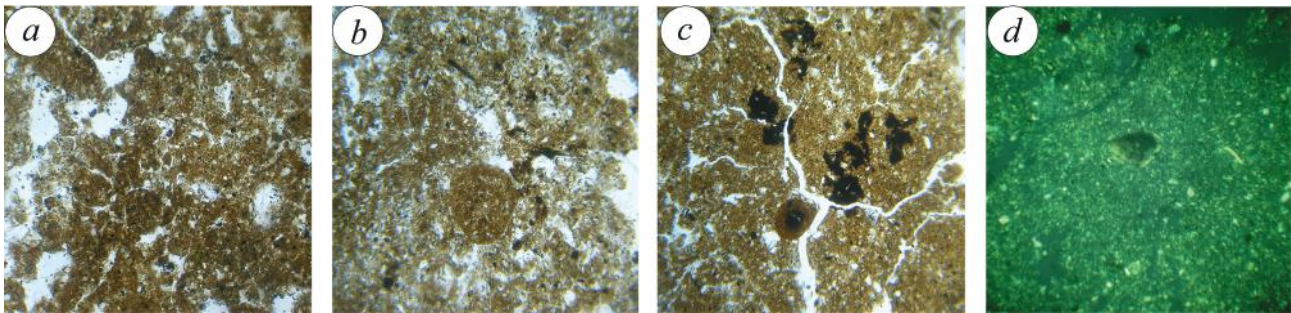


Fig.1. Microstructure of reddish-brown (kr_{b2}) Kryzhanivka soil (village of Melekine): *a* – round form of accumulation of iron-clay material; *b* – segregation of iron-clay material; *c* – iron-manganese stains and microortshteins on the background of iron-clay plasma; *d* – plasma infiltration by microcrystalline calcite (*a-c* – nic. ||, *d* – nic. +, magnification 100)

Lower reddish-brown soil (kr_{b1}) reflects somewhat damper conditions of its formation compared to the upper ones. It is more ferruginous, clayed, in the microstructure, signs of reorientation of clay and iron-clay material with concentrations of ferruginous mull humus in the bundles and lumps are defined. Clay and iron-clay plasma in the lower part is more impregnated with microcrystalline calcite, as well as more intensely colored with oxides and hydroxides of iron and manganese near pores (Fig.2).

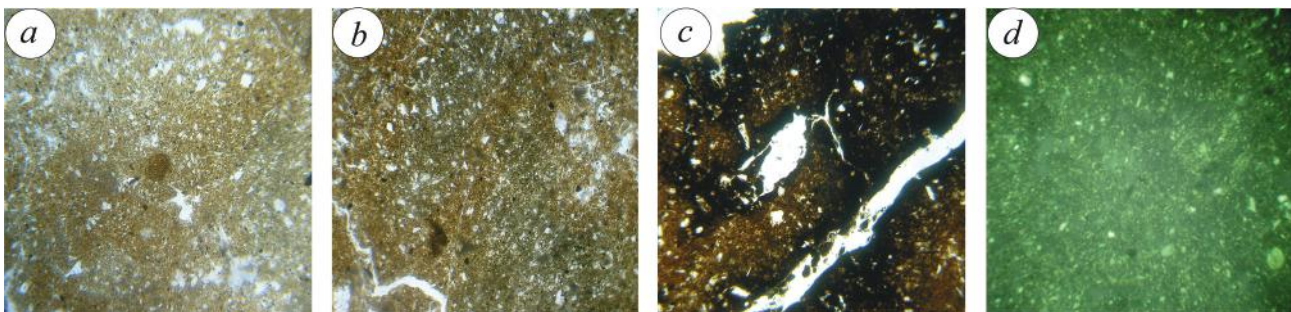


Fig. 2. Microstructure of reddish-brown (kr_{b1}) Kryzhanivka soil (village of Melekine): *a, b* – signs of displacement of clay and iron-clay material; *c* – concentration of clay material impregnated with hydroxides and iron oxides and manganese near pores; *d* – plasma penetration by microcrystalline calcite; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

The indicated signs (capacity of the profile, clay composition, ferrugination, reddish shades in color) show that formation of Kryzhanivka soil was in a warm, moist (change-humid), close to arid subtropical climate. But at the same time, the soils reflect the intensification of the processes of steppe growing in landscapes (if compare with the northern territories where reddish, red-brown, alkali free forest and meadow soils were formed), they changed with more steppe differences – red-brown (kr_{b2}) and reddish-cinnamon (kr_{b1}) carbonated.

Shyrokyno horizon (OIS – 35-21) (Gozhik e. a.,

2012). By paleopedological data on the territory of the Azov Lowland were characterized with reddish-cinnamon (sh_{b2}) and cinnamonish-brown (sh_{b1}) soils, which as Kryzhanivka, are subarid soil formation.

The upper reddish-cinnamon soil (sh_{b2}), investigated in the section village Melekine, is somewhat lixiviated from carbonates (in the lower part their number increases – carbonate-clay plasma is impregnated with microcrystalline calcite) and is characterized by a nuttish-prismatic structure, an argillaceous composition, in the form of blocks with a large number of nodules with concentration of organo-clay material (Fig.3). The type of the profile, the intensive ferrugination, claying, which is most

defined in the middle part of the profile, the features of lixiviation indicate the signs of warmer and humid conditions of soil formation, compared with the Martonosha and Lubny soils of the lower Pleistocene.

The lower cinnamonish-brown soil (sh_{b1} – the vil. of Bezimenne) differs from the reddish-brown (sh_{b2}) stronger profile (1.50m), is much clayed, ferruginous, carbonate, with a significant development of complex microaggregates of the I-II order, the presence of nodules with concentration of organo-clay, clay and iron-clay material (their formation is probably connected with meadow processes and with periodic

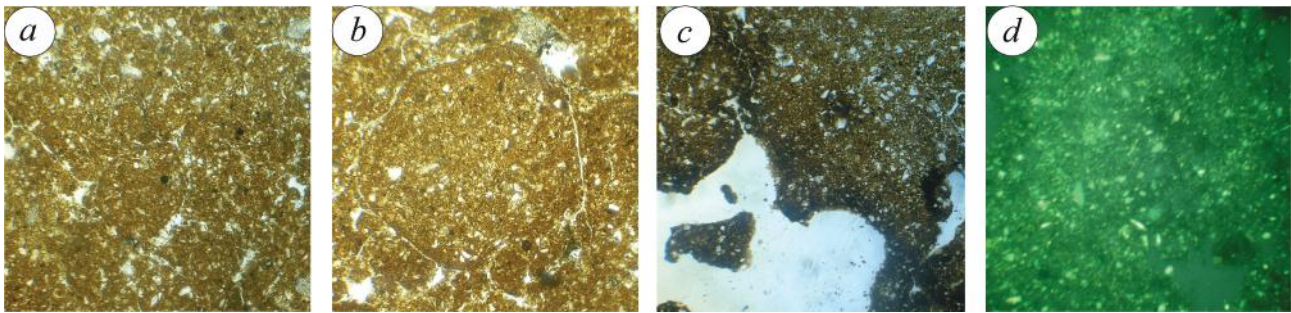


Fig. 3. Microstructure of reddish-cinnamon (sh_{b_2}) Shyrokyno soil (village of Melekine): *a* – segregational clusters of organo-clay material separated by pores; *b* – large (0,7 mm) cluster of iron-clay material; *c* – carbonate-clay plasma, paintwork pores with oxides and hydroxides of iron and manganese; *d* – uniform concentration of grains of microcrystalline calcite in plasma; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

excess moisture), iron-clay microortshteins (processes of redistribution of iron oxides and manganese, pulling them to the edges of pores-cracks), microcrystalline calcite (Fig.4). All these signs indicate a somewhat wetter conditions for the formation of this soil.

Shyrokyno soils are quite close to the Martonosha

soils (2.0m thickness) were developed. They are characterized by a dark gray with a reddish tinge color of the profile, are more clayed and ferruginous compared with the Lubny and form one polygenetic profile in which some soil formation stages ($mr_{b_2} + mr_{b_1}$) are combined. The meadow-reddish-cinnamon dark-

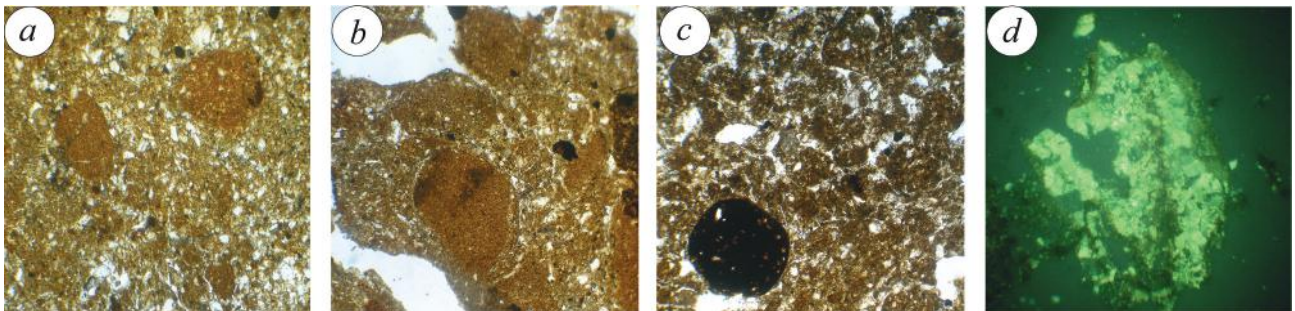


Fig. 4. Microstructure of cinnamonish-brown (sh_{b_1}) Shyrokyno soil (village of Bezimenne): *a* – uniform impregnation of plasma by iron-clay material, nodules, clusters of iron-clay material; *b* – round segregational clusters of clay and iron-clay material; *c* – iron-manganese microortshteins, uniform plasma impregnation with humus and its rounded clusters; *d* – accumulation of fine-crystalline calcite grains (*a-c* – nic. ||, *d* – nic. +, magnification 100)

signs, but they are characterized by a more intense reddish tinge of the color of the profile, they are more ferruginous (iron-clay plasma), clayed (the number of nodules with concentration of organo-clay, clay and iron-clay material is much larger). In comparison with the soils which were formed to the north, the studied soils of the Azov Lowland is differed in a higher position of the carbonate horizon, the presence along with the blocks of aggregate microconsolidations and the impregnation of the plasma by microcrystalline calcite in the middle and lower parts of the profiles, indicating somewhat arid conditions of the warm-moderate close to subtropical climate.

Martonosha horizon (OIS – 19-17) (Gozhik e. a., 2012). On the territory of the study during the Martonosha period soils, as in well as the Shyrokyno and Kryzhanivka time, are characterized by a reddish tinge of the color of the profile, are clayed, ferruginous.

Near village of Melekine dark-colored fused

colored soil of the climatic optimum mr_{b_2} is lixiviated from carbonates (“washed” carbonates accumulate in cinnamonish-brown loess-liked material (mr_{b_2})), with carbonate concretions, light carbonate-clay plasma and clusters of microcrystalline calcite), with gypsum and shows signs of net-like orientation of clay with spots of manganese in the lower part (Fig.5). The material of the reddish-light-brown dark-colored soil of the climatic optimum, mr_{b_1} , is more ferruginous (enriched in iron and aluminum compounds), clayed (presence of clay particles) and with carbonate (concretions) compared to the upper (mr_3). For the soil also characterized by a lesser manifestation of the signs of reorientation of clay and skeletal material and some gleying (meadow formation conditions).

In Martonosha time in the section village of Bezimenne were investigated reddish-cinnamon-brownish fused saline soils (1.0m) mr_3 substrate, with features of the steppe (in the upper and middle

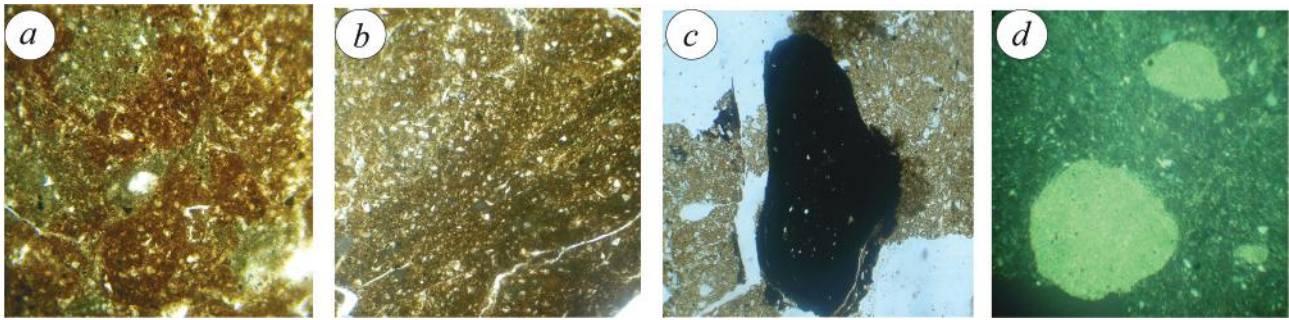


Fig. 5. Microstructure of dark-colored (meadow-reddish-cinnamonic) fused – $mr_{b2} + mr_{b1}$) Martonosha soils (village of Melekine): *a* – rounded clusters of iron-clay material; *b* – displacement of clay and skeletal material; *c* – iron-manganese microorganisms elongated form; *d* – the rounded concentration of microcrystalline calcite in a plasma; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

sections of the profile – the development of complex microaggregates to the III order and the nodules with segregations of the organ-iron-clay material, the isolation of calcite in plasma, and about pores throughout the profile) and meadow (in the bottom – the presence of glazed micro-sections and gypsum, slight movement of clay) soil formation (Fig.6).

Compared to the Kryzhanivka and Shyrokyne, the Martonosha soils are characterized by less

polygenetic profile and reflect an increase in signs of xerophyticity that was characteristic of the conditions of the southern and southeastern parts of Ukraine. All these features indicate the conditions of formation of these enriched, composed in the form of blocks with organo-clay soils, when the climatic conditions were warm-temperate and close to subtropical ones (warmer in comparison with the Zavadiivka and especially the Lubny soils). Probably in the first half

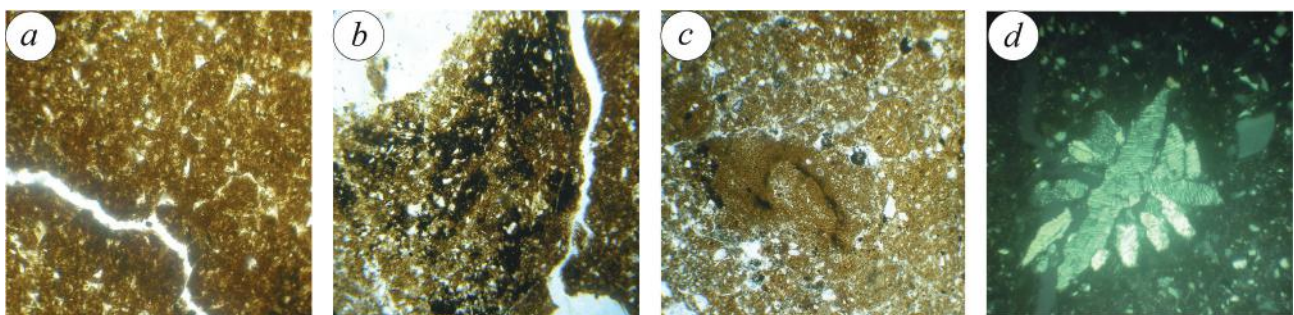


Fig. 6. Microstructure of reddish-cinnamonic fused saline (mr_3) Martonosha soil (vil. of Besimenne): *a* – rounded clay segregation separated by pores; *b* – iron-manganese stains; *c* – signs of the of iron-clay material transfer; *d* – concentration of gypsum in the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

thickness of soil profiles, with a lack of well-defined genetic horizons, are not so ferruginous (though they are noticeably enriched in hydroxides of iron and aluminum) and clayed, with less number of nodules with concentration of organo-iron-clay material. The soils also have dark brown and reddish-dark-cinnamonic color (the highest intensity of reddish coloration in the middle part of the profile), compactness, fusion, high clayed with microforms of some mobility of clays, manganese and iron along the pores with the impregnation of plasma by microcrystalline calcite. All this determines their high viscosity in the humid state and fusibility, density and cracks in drying. Increased Martonosha soil hydromorphism is due, apparently, not only to the abundance of atmospheric precipitation, but also to the close occurrence of ground water. Soils of different stages often form a

of the optimum the climate was relatively humid, in the second – the variable-humid, close to the climate of the current alternating-humid subtropics, but with clearly detected hydromorphy of landscapes. This contributed to the development of meadow processes (the formation of powerful profiles with high mineral dispersion), which, in combination with periodic aridation, rising to the final phase of the Martonian time, caused the fusion of these soils.

Lubny horizon (OIS – 15-13) (Gozhik e. a., 2012). Lubny soils, as well as Martonosha, are characterized by the active development of soil formation processes, but in more moderate and more contrasting climatic conditions. This is confirmed by the formation of the soil of the sub-boreal climate on most of the territory of Ukraine at that time, and only in the steppe (including the territory of the Azov lowlands), the Lubny soils

had some features of the subtropical. The soils of the Lubny horizon are very well expressed in the studied sections, they are characterized by brownish-gray shades of color of their profile, but always with a cinnamonic tint. Only in the Lubny soils in the lower Pleistocene complex microaggregates is developed and humus is concentrated in the humon. They also noted the features that are characteristic to the Kryzhanivka, Shyrokyno and Martonosha soils: some material clayed (more intensively in the middle part of the profile), with compact building, it is characteristic nodules with concentration of organo-clay material (apparently associated with meadow processes), visible features the movement of clays (mainly within the genetic horizons), iron and manganese in the form of a large number of microortshteins, darker coloration of the pores, simultaneously with the isolation of calcite and gypsum.

The reddish-brown saline soil of the climatic optimum lb_{b_2} (vil. of Melekine) has a cinnamonish-brown-reddish coloration of the whole profile (the clayed and density of the middle part), the presence of gypsum concentrations. Micromorphology of the soil is characterized by a manifestation of signs of reorientation of clay material, the presence of clear blocks with concentration of organo-clay material, microortshteins in the middle and lower parts of the profile, which are signs of raining processes and salinization in the formation of soil, due to periodic

processes of excess moisture. The presence of complex microaggregates (although their number is negligible), the saturation of carbonates (the impregnation of plasma by microcrystalline calcite and gypsum with its concretions) are signs of the influence of steppe conditions and salinity in the formation of this soil.

In the section of the village of Besimmenne an unidentified brown-cinnamonic, dark-colored saline soil, which is characterized by a polygenetic profile (lb_{b_2} : He, Hpki, Pks and lb_{b_1} : Hpk, Pk), was detected. The climate of the climatic optimum (lb_{b_2}) is characterized by the signs of steppe soil formation (lumpy-granular structure, the presence of moleholes and wormholes, the development of complex microaggregates to the third order separated by pores and nodules with concentration of organo-clay material in conjunction with the impregnation of the plasma by microcrystalline calcite). At the same time, its profile is saline in the middle part, with the traces of reorientation of clay and the presence of a significant amount of microortshteins (Fig.7). The lower soil of the climatic optimum lb_{b_1} reflects the features of meadow-steppe signs of soil formation and differs in the smaller development of complex microaggregates, but with more iron-manganese microortshteins (periodicity in moisture).

The definite signs indicate that climatic conditions in the territory of the Azov lowland during

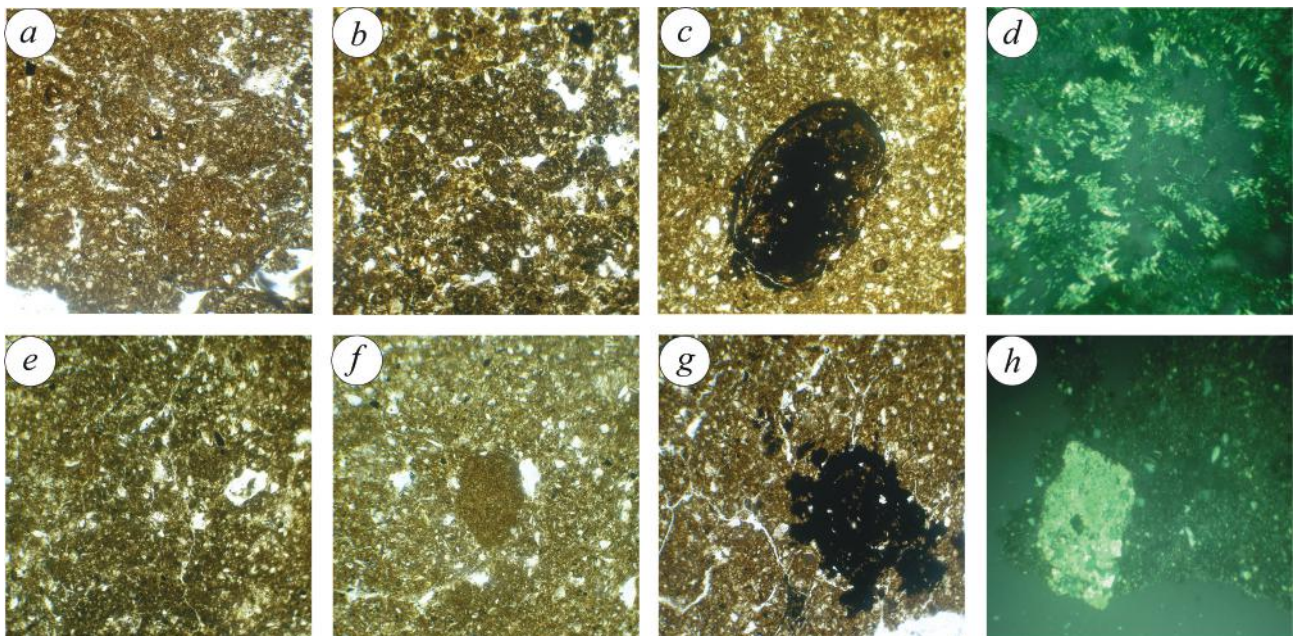


Fig.7. Microstructure of dark-colored (brown-cinnamonic) fused ($lb_{b_2} + lb_{b_1}$) Lubny soil (village of Bezimmenne): *a* – round segregational clusters (0,2mm) of iron-clay material; *b* – complex rounded microaggregates of the I-II order, separated by pores; *c* – uniform impregnation of the plasma with clay, iron-manganese microortshteins (0.5mm) of concentric microstructure; *d* – small crystals of gypsum; *e* – complex microaggregates of II order, separated by pores; *f* – round segregation of clay material; *g* – there are blocks separated by pores, iron-manganese stain; *h* – concentration of micro- and small-crystalline calcite in a pore; (*a-c*, *e-g* – nic. ||, *d*, *h* – nic. +, magnification 100)

the formation of the Lubny soils were quite warm, close to subtropical ones (ferrugination, claying and carbonation of the profile), but more moderate and not as warm as in the Zavadivka and Martonosha times. The soils are clayed and ferruginous, but to a lesser extensively than Martonosha and differ from them in grayish shades of coloring profiles. The studied soils are saline, with clear blocks and clutches of organo-iron-clay material and features of redistribution of clays within the genetic horizons. The soil lb_{b1} (vil. of Bezimenne) is characterized by a deeper playing of the carbonate horizon and a large number of microortshteins. The lower soil of the climatic optimum (lb_{b1}) was definitely formed in meadow-steppe conditions, and the upper (lb_{b2}) – steppe.

Zavadivka horizon (OIS – 11) (Gozhik e. a., 2012). In Zavadivka time were investigated reddish-

concentrations of gypsum. Micromorphology of the soil is characterized by the presence of a significant number of segregational clusters of organ-iron-clay material, complex microaggregates of the I-II orders, and the impregnation of the plasma in the carbonate horizon by micro- and small-crystalline calcite (Fig.8).

The cinnamonic saline soils with the chernozem-like profile of the climatic optimum zv_{b1} (vil. of Melekine) differs from the reddish-cinnamonic saline soil zv_{b2} by greater claying, density of profile with cracking pores and drosses of gypsum and manganese puncturing. They are also less ferruginous, aggregated (less complex microaggregates of the I-II order and the separation of organo-clay material on the background of a dense block microstructure with cracking pores) and carbonate and shows signs of a

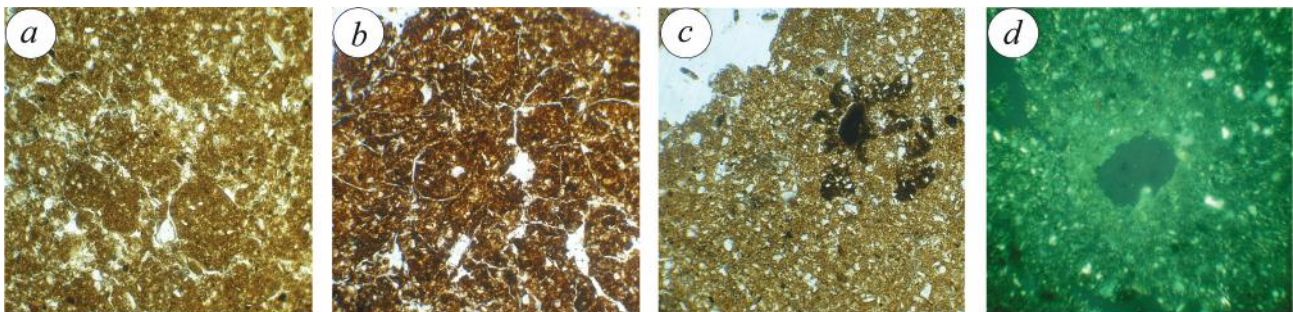


Fig. 8. Microstructure of reddish-cinnamonic saline (zv_{b2}) Zavadivka soil (village of Melekine): *a* – nodular segregational clusters of organo-clay material; *b* – iron-clay plasma, rounded segregational clusters of iron-clay material, separated by pores; *c* – dense packing of skeleton grains in clay plasma, spots of manganese; *d* – concentration of microcrystalline calcite in the plasma and near the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

cinnamonic saline (zv_{b2}), brown saline (zv_{b1}) the villages of Melekine and cinnamonic soils are also the climatic optimum zv_{b1} (vil. of Bezimenne).

The reddish-cinnamonic saline soil (vil. of Melekine) of the climatic optimum zv_{b2} is characterized by a reddish (ferruginous) shade of the color of the profile, a prismatic-nutty structure, a significant amount of carbonate nodules and

slight reorientation of the material (jet orientation of the clay substance, the presence of disaggregated microdistricts and zones depleted on clay – Fig.9). Such signs of the soil indicate its formation in more humid conditions compared with the upper reddish-cinnamonic saline soil (zv_{b2}).

Besides brown saline soils (vil. of Melekine) we also had researched cinnamonic soil of climatic

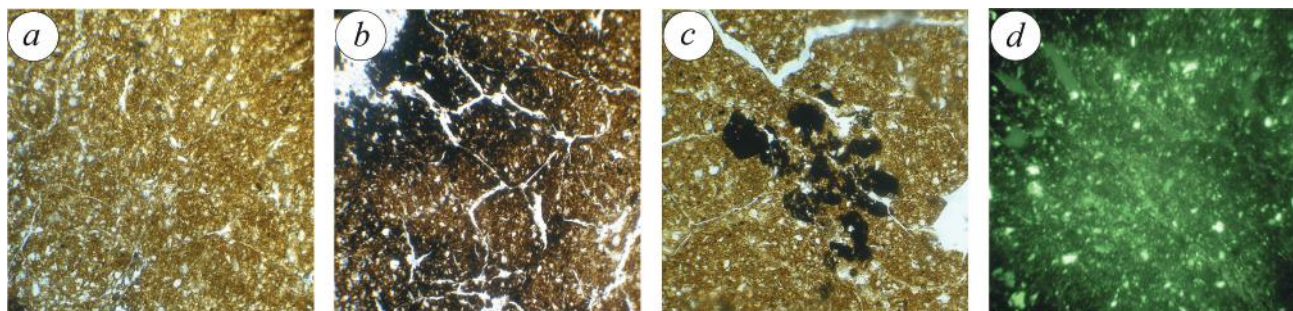


Fig. 9. Microstructure of brown saline (zv_{b1}) Zavadivka soil (village of Melekine): *a* – isolation of organo-clay in the form of simple and complex microaggregates of I-II order, separated by twisted pores; *b* – segregation of organo-clay impregnated with oxides and hydroxides of iron and manganese, separated by pores; *c* – iron-manganese stains; *d* – dusty-plasma microstructure, jet orientation of clay material; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

optimum zv_{b1} (vil. of. Bezimenne), with a clear horizon of carbonates (carbonates in the form of concretions) and without gypsum. Compared to the soils formed in the north, cinnamonic soils reflect us the features of some soils characteristic for the southern part of Ukraine (the development of complex microaggregates to the III order, the gradual decrease of humus with depth, the presence of the carbonate horizon with carbonate-clay plasma which uniformly impregnated with microcrystalline calcite) and some waterlogging (a significant number of segregation clusters of organo-clay and clay materials, the presence of microortshteins).

(vil. of Melekine), is characterized by a brown-gray coloration of the profile, lumpy structure, the presence of quinces, moleholes and carbonates in the form of veins and nodules. Micromorphologically, the soil is characterized by such microindications (Fig.10): complex microaggregates and porosity (the development of complex microaggregates to the third order, separated by a system of winding pores), various isolation of carbonates (plasma infiltration by microcrystalline calcite, its concentration near pores). Compared to the northern sections, the soil reflects the features of some steppe processes (shortened profile – 0,60m, the presence of complex aggregates,

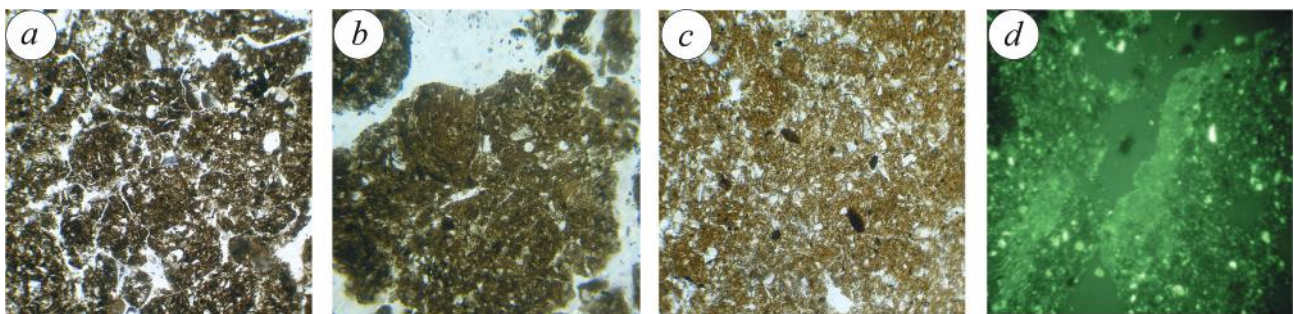


Fig. 10. Microstructure of Kaydaky ordinary chernozem (kd_{b2}) (village of Melekine): *a* – humus-clay plasma, complex microaggregates of II-III order, separated by pores; *b* – plasma impregnation with humus, isolation (0.2mm) of organo-clay material; *c* – carbonate-clay plasma, small microortshteins; *d* – concentration of microcrystalline calcite in the plasma and near the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

Probably, during the Zavadvka time in the Azov Lowland, the climatic conditions were warmer, even hot, in comparison with modern ones (large ferrugination of soils, often their saline). Although compact structure and inhomogeneous coloration of the profile is characteristic for the Lower Pleistocene (Martonosha, Lubny) soils, in the Zavadvka soils it is also preserved. Probably the soils were formed in moderate variable-humid (in the presence of periods of drying), close to subtropical climatic conditions and represent a transitional version to temperate climates, which became widespread in the post-Dnieper times.

Kaydaky horizon (OIS – 7) (Gozhik e. a., 2012). During the Kaydaky time there were more sharp climatic changes caused by Dnieper glaciation. It's influence also affected the development of soil cover. Instead of the subtropical soils that were distributed in the Pliocene, and in the south and in the Early (Martonosha, Lubny horizon) of the Pleistocene, the temperate continental climate of the Kaydaky period begins to form similar to the modern ones. On the territory of the Azov Lowland, we have investigated the soils of the optimal stage: ordinary chernozem (kd_{b2}) – village of Melekine and Bezimenne and cinnamon-brown soils (kd_{b1}) – village of Melekine.

Ordinary chernozem of climatic optimum kd_{b2}

impregnation of the plasma by microcrystalline calcite). The climate of the climatic optimum, kd_{b2} , according to it's morpho- and microstructure features is most closely related to modern zonal soils (chernozem, the usual) that are developing in this territory, although the climate at that time was definitely a bit more evenly humid.

The lower, cinnamonish-brown soil of the climatic optimum kd_{b1} (village of Melekine) is characterized by a combination of meadow germs (the development of segregation clusters of organo-clay material, signs of weak mobility of silt, plasma penetration by oxides and hydroxides of manganese and its isolation in the form of spots and microortshteins) and steppe (small power, poorly differentiated profile, clear grayish tint in the background of light brown color, complex microaggregating, plasma penetration by microcrystalline calcite in the middle and lower part of the profile) processes of its formation. From the upper (kd_{b2}) soil, it is differed by less complex microaggregates and carbonates (Fig.11).

According to paleopedological data, it can be concluded that the climatic conditions of the Kaydaky time in the territory of the Azov lowland, as well as for the whole of Ukraine, have changed. In the first half of the optimum the soils of the forest-grass

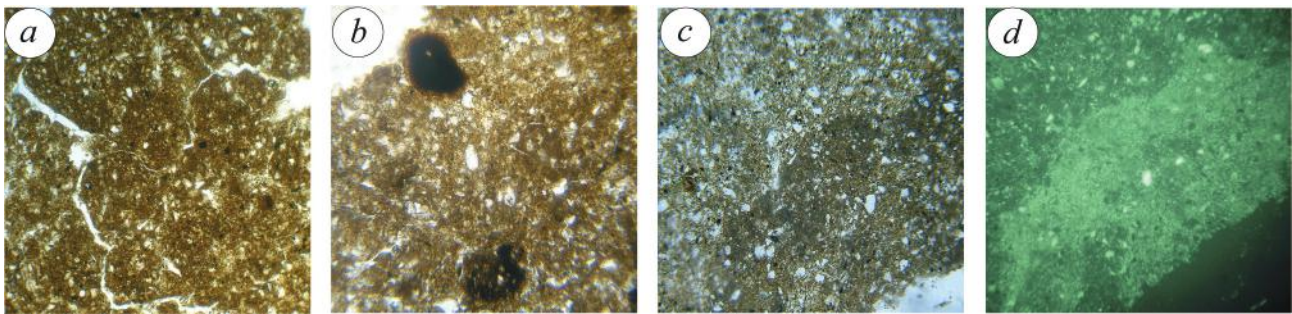


Fig. 11. Microstructure of cinnamonish-brown (kd_{b1}) Kaydaky soil (village of Melekine): *a* – rounded segregational clusters of organo-clay material separated by pores; *b* – dense packing of grains of the skeleton in clay plasma, iron-manganese microortshteins; *c* – plasma impregnation with microcrystalline calcite; *d* – concentration of microcrystalline calcite in the plasma and near the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

genesis were formed. By the end of the stage, the climate has changed considerably in the direction of continentalization – soils of the chernozem type are developing in the soil cover (kd_{b2}). But the increased meadowness of these chernozems indicates conditions that are more damp than the modern southern zone of chernozem soil formation on the territory of Ukraine. In general, Kaydaky soils reflect more contrasting warmly-moderate conditions of their formation, have a well-formed profile with the genetic horizons of soils of the boreal, sub-boreal type of temperate-warm and temperate continental climate. The features of the upper climatic optimum (kd_{b2}) resemble the profile of modern soils, but those formed in slightly more evenly humid conditions. Kaydaky soils are most similar to the soils that are currently forming in Ukraine, although some of their features indicate a more humid conditions for their formation, while others are more warm.

The cinnamonish-gray saline soils of the climatic optimum pl_{b1} (village of Melekine and Bezimmenne) are characterized by the following signs of morpho- and microstructure (Fig.12): dark gray coloration of the profile with a distinct cinnamonish tinge, lumpy-nutty structure, clayed, fusion, well formed carbonate-gypsum horizon, the development of complex microaggregates to the III order, separated by pores, the dispersed state of humus, the presence of microortshteins, grains of micro- and small crystalline calcite and gypsum of leafy-plaster form. In the upper part, due to the saline, the soil shows signs of a slight nettish orientation of the clay material. The presence and concentration of a large number of microortshteins indicates a certain periodicity in the moisture of these soils. Apparently, the soils were formed in the conditions of a southern meadow grass steppe of moderately warm climate and combine some of the properties of chernozem and chestnut soils.

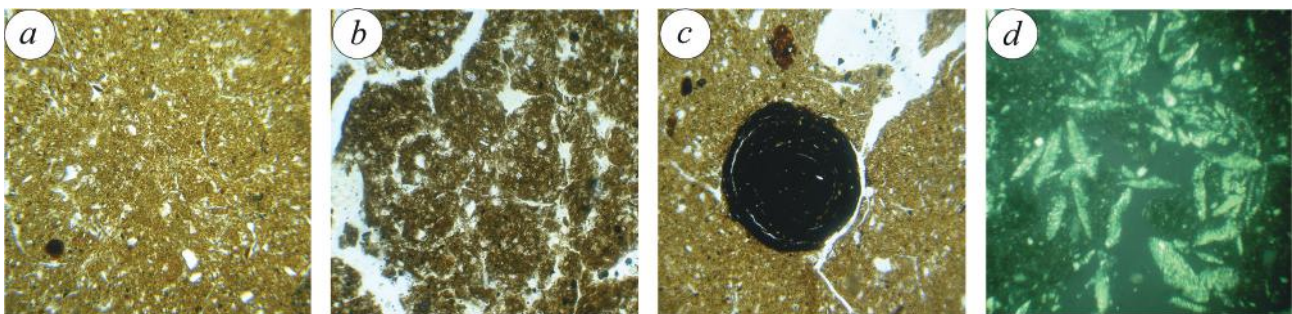


Fig. 12. Microstructure of cinnamonish-gray saline (pl_{b1}) Plylucky soil (village of Melekine): *a* – clay plasma of the base, simple and complex microaggregates of the II-III order of a rounded form, separated by thin winding pores; *b* – round segregation of organo-clay material separated by pores; *c* – concentric glandular manganese microortshtein; *d* – concentration of small plaster crystals in plasma; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

Prylucky horizon (OIS – 5) (Gozhik e. a., 2012).

On the territory of the Azov lowland, we were found near vil. of Bezimmenne the svit of Prylucky soils (cinnamonish-gray saline – pl_{b1} , chernozem saline – pl_{b2} , brown steppe – pl_c) and cinnamonish-gray saline soils of the climatic optimum pl_{b2} (village of Melekine).

The chernozem saline of climatic optimum pl_{b2} (village of Bezimmenne) is dark gray with a brown tinge with profile color, lumpy structure, the presence of moleholes and carbonates in the form of impregnation and mycelium. The soil, in contrast to the corrosion-gray saline soils (pl_{b1}), is better microaggregated over the entire profile (complex microaggregates of the

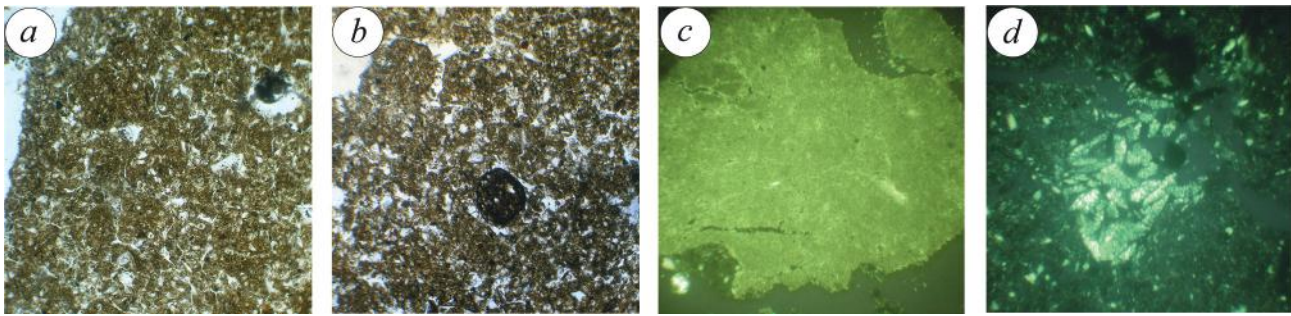


Fig. 13. Microstructure of Pryluky (pl_{b_2}) chernozem saline (village of Bezimenne): *a* – uniform impregnation of the plasma organo-clay material, simple and complex microaggregates of I-II order, separated by pores; *b* – complex microaggregates of the III order, round form (0,15mm), separated by pores, iron-manganese microortshtein (0,15mm); *c* – cluster of microcrystalline calcite; *d* – concentration of gypsum in the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

I-III order) with the presence of micro- and small crystalline calcite grains in carbonate-clay plasma, but less porous (a small number of gypsum crystals in the upper and lower parts of the profile – Fig.13).

The brown weakly developed steppe soil of the final stage pl_c (village of Bezimenne) is characterized by poor development of complex microaggregates of the I-II order, uniform saturation of the plasma by microcrystalline calcite.

Pryluky soils – cinnamonish-gray saline (pl_{b_1}), chernozem saline (pl_{b_2}), brown steppe (pl_c) reflect conditions of a moderately warm climate (wetter and warmer in comparison with modern ones) of the southern grassland steppe. Soils, forming the suit of soils ($pl_{b_1} + pl_{b_2} + pl_c$) reflect changes in conditions of moderately warm climate during the stage. The most humid conditions were during the formation of cinnamonish-gray saline (pl_{b_1}), somewhat less humid – chernozem saline (pl_{b_2}) and much less moist – brown steppe (pl_c) soil. Pryluky soils, as well as Kaydaky are the closest to the soils that are currently forming

zone, but in more arid conditions (compared to the northern territories). Natural zones of Ukraine at the modern time, in comparison with the Kaydaky, were displaced to the south.

Vytachiv horizon (OIS – 3) (Gozhik e. a., 2012).

In the Vytachiv time, the cinnamonish-brown (similar to chestnut) clay optimum vt_{b_2} soils (sections the villages Melekine and Bezimenne) were investigated.

Morphologically, the soils are characterized by a cinnamonish-brown coloration of the profile, a considerable clayed of its middle part, with carbonates in the form of impregnation, white bilozirka other and concretion. Under a microscope for soil material, the development of simple and complex microaggregates of the III order is characteristic, as well as the concentration of the organo-clay material, the spatial structure of the clay, the presence of microortshteins, and the saturation of the plasma by microcrystalline calcite (Fig.14).

Such morpho- (cinnamonish-brown coloring, profile reduction and its riching in carbonates, high

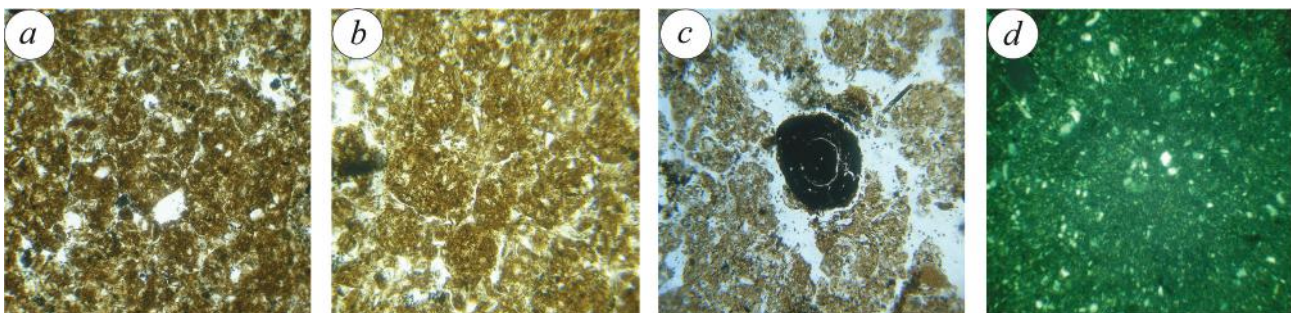


Fig. 14. Microstructure of cinnamonish-brown (vt_{b_2}) Vytachiv soil (village of Melekine): *a* – simple and complex microaggregates of the I-III orders of round form (0,12mm), separated by pores; *b* – nodules with segregations of organo-clay material; *c* – iron-manganese microortshtein (0,25mm); *d* – dusty-plasma microstructure, uniform concentration of microcrystalline calcite in plasma; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

in Ukraine, although some features indicate a more humid conditions for their formation, while others are more warm. In comparison with the Kaydaky, Pryluky soil formation took place in somewhat more steppe conditions, although in one moderately warm

absorption, especially in the middle part) and micro sign (the presence of nodules) of soils indicate their development in fairly warm and relatively humid conditions. It is possible that the moisture of these soils was periodic: in the humid season, the

soil-forming process proceeded in the direction of brownzems formation, and in dry period under the steppe type. Such periodicity of humidification is confirmed by micromorphological data (development of concentration of organo-clay material, concentric microortshteins, along with plasma by microcrystalline calcite). However, the insignificant power of the Vytachiv soils (0.70m), the presence of moleholes, high degree of carbonatisation with the isolation of the carbonate horizon indicates rather dry conditions of formation. Probably the Vytachiv soils in this territory have developed in rather warm conditions of periodically arid temperate and warm subarid climate and have no analogues in the modern soil cover.

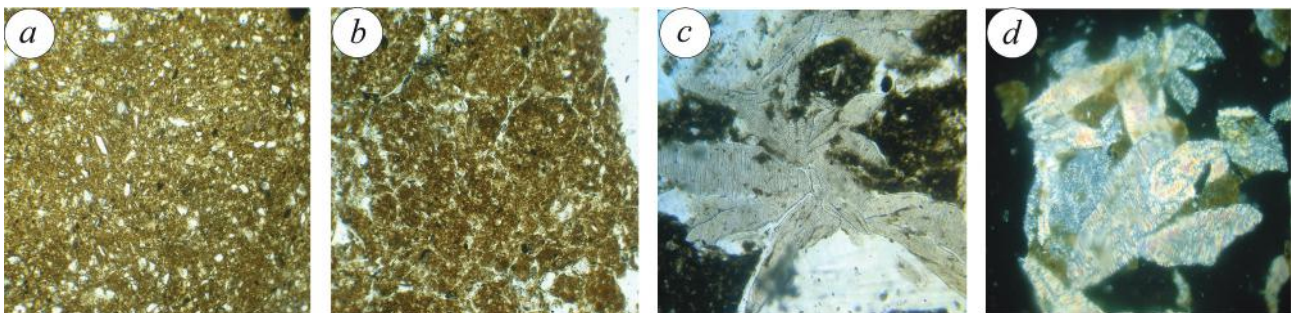


Fig. 15. Microstructure of the Dofinivka (df_{b_2}) chernozem saline (village of Melekine): *a* – compact packing of grains of the mineral skeleton in the humus-clay plasma; *b* – simple and complex microaggregates of the III order (0,1mm), separated by pores; *c* – large crystals of gypsum; *d* – tabular crystals of gypsum; (*a*, *b* – nic. ||, *c*, *d* – nic. +, magnification 100)

Dofinivka horizon (OIS – 2) (Gozhik e. a., 2012). The morpho- and micromorphological properties of the Dofinivka soils reflect the features of the Pleistocene trends to climate aridisation. This is confirmed by the formation of the chernozem of saline soils (df_{b_2}), steppe brown saline soils and brown desert-steppe soils in the final stage (df_c) of the Dofinivka soil formation.

The Dofinivka climatic optimum soil df_{b_2} chernozem saline (village of Melekine) is characterized by a dark gray color, the presence of moleholes, wormholes, carbonates and niddles of gypsum, the development of simple and complex of I-II order microaggregates,

(0.30m) fulvous saline soils (simple and complex microaggregates of the II order, uniform impregnation of the plasma by microcrystalline calcite and gypsum) were investigated in the section the villages of Melekine and brown desert-steppe soils (light-boring color, powdery forms of carbonates, spongy microstructure, simple and complex to the II order microaggregates, separated by pores, plasma infiltration by microcrystalline calcite – Fig. 16) – vil. of Melekine, Bezimenne.

The morpho- and micromorphological properties of the Dofinivka soils reflect the features of the Pleistocene's subsequent climate aridization.

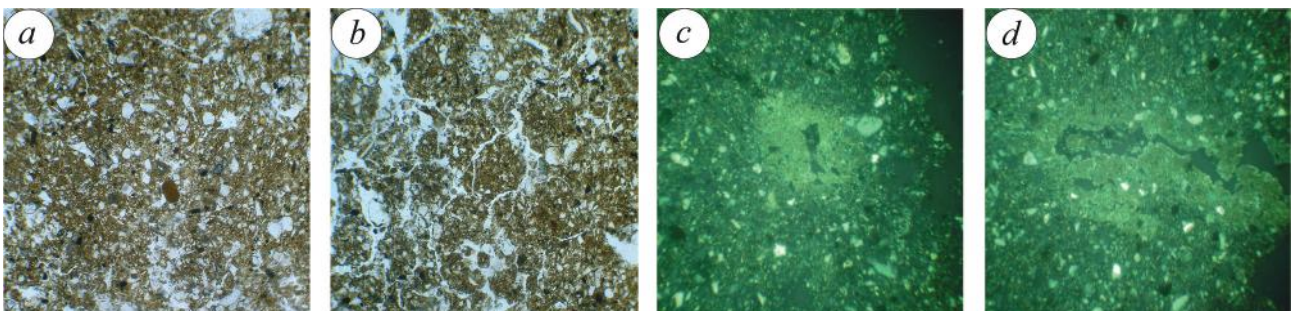


Fig. 16. Microstructure of brown desert-steppe (df_c) Dofinivka soil (villag. of Melekine): *a* – compact building, dense packing of grains of mineral skeleton in carbonate-clay plasma; *b* – complex microaggregates of the II order, separated by winding pores; *c* – dusty-plasma microstructure, concentration of microcrystalline calcite in the pores; *d* – concentration of microcrystalline calcite in a pore; (*a*, *b* – nic. ||, *c*, *d* – nic. +, magnification 100)

Insufficient moisture has led to the formation of chernozem, which had clear features of xeromorphism (without signs of redistribution of organo-mineral substances by profile), their profiles are carbonate, often with gypsun. Xerophytization of conditions has been especially intensified in the final stage of the Dofinivka soil formation (the formation of brown desert-steppe soils). The Dofinivka soils, in comparison with modern ones, have a higher aridity of the conditions for the formation of a temperate dry continental climate, but warmer compared with the Prychernomorsk time.

Paleopedological results obtained by the author in person (Karmazinenko, 2013, 2014, 2017) and the usage of literary data (Veklych, 1982, 1987; Krokmal, Rekovets 2010; Sirenko, Turlo 1986) made it possible not only to reconstruct the Pleistocene soils, but also to follow the change of paleogeographic conditions (types of soils, general types of vegetation, faunistic

complexes, and climate) during the Dofinivka, Vytachiv, Pryluky, Kaydaky, Zavadivka, Lubny, Martonosha, Shyrokyno and Kryzhanivka stages in the Azov Lowland (Table 1).

Conclusions. Paleopedological studies (using micromorphological analysis) of the Pleistocene soils of the Kryzhanivka, Shyrokyno, Martonosha, Lubny, Zavadivka, Kaydaky, Pryluky, Vytachiv and Dofinivka stratigraphic horizons near the villages of Bezimenne and Melekine in the Azov Lowland made it possible to determine their morpho- and micromorphological features, to establish the types of these deposits and to reconstruct the paleogeographical conditions of the time of their formation:

- Kryzhanivka (reddish-cinnamon – kr_{b1} , reddish-brown – kr_{b2}), Shyrokyno (cinnamonish-brown – sh_{b1} , reddish cinnamon – sh_{b2}) and Martonosha (dark-colored (meadow-reddish-brown) merged – $mr_{b2} + mr_{b1}$, reddish-cinnamon brownish fused saline

Table 1. Paleogeographic conditions of the Pleistocene in the Azov lowland (Veklych, 1982, 1987; Krokmal, Rekovets 2010; Sirenko, Turlo 1986.)

Stage	The type of soils which studied palaeopedologically by the author sites (vil. of Bezimenne, Melekine)	The general types of vegetation (Sirenko, Turlo 1986)	Faunistic complexes for large mammals (Krokmal, Rekovets 2010)	Climate (average annual temperature, °C: January/ July; annual rainfall, mm (Veklych, 1982, 1987; Sirenko, Turlo 1986)
df	chernozem saline (df_{b2}), brown saline (df_c), brown desert-steppe (df_c)	grass-graze-polynomial-loboda steppes	Upper paleolithic (<i>Mammuthus primigenius</i>)	moderate dry (-6- -9 / +17- +18; 300-400)
vt	cinnamonish-brown (vt_{b2})	grass-gravel steppes and ravine forests		moderately warm subarids (-3- -5 / +18-+20; 350-450)
pl	cinnamonish -gray saline (pl_{b1}), chernozem saline (pl_{b2}), brown steppe (pl_c)	grass-gravel steppes		moderately warm (0-+1 / +21- +22; 450-700)
kd	cinnamonish-brown (kd_{b1}), chernozems ordinary (kd_{b2})	grass-gravel steppes and ravine forests	Khazar (<i>Mammuthus chosaricus</i>)	moderately warm (-2- -3 / +20-+21; 550-700)
zv	cinnamon (zv_{b1}), reddish-cinnamon saline (zv_{b2})	forest-steppe with broadleaf pine forests with elements of Pliocene flora with grass-mixed grass steppes	Singh (<i>Palaeoloxodon antiquus</i>)	moderately variable and humid close to subtropical (0- +2 / +22-+23; 400-600)
lb	reddish-brown saline (lb_{b2}), dark-colored fused ($lb_{b2} + lb_{b1}$)	forest-steppe with broadleaf-pine forests with elements of Pliocene flora and meadow steppes	Tiraspol (<i>Archidiskodon trogontherii</i>)	moderately warm transition to subtropical (-1-+1 / +21-+22; 550-900)
mr	dark-colored merged ($mr_3 + mr_2 + mr_1$), reddish-cinnamon fused saline (mr_3)	forest-steppe with broadleaf-coniferous forests with elements of the Pliocene flora and mesotic steppes		warm-moderately close to subtropical (+1-+2 / +22-+23; 650-750)
sh	cinnamon (sh_{b1}), reddish-cinnamon (sh_{b2})	forest-steppe with broadleaf-coniferous forests with elements of heat-loving flora and meadow-steppe herbaceous vegetation	Taman (<i>Archidiskodon meridionalis tamanensis</i>)	warm-moderate close to subtropical arid (+1-+3 / +22- +24; 550-650)
kr	reddish-cinnamon (kr_{b1}), reddish-brown (kr_{b2})	forest-steppe with broadleaf coniferous forests including elements of heat-loving flora and grassy steppes	Pseudo (<i>Archidiskodon meridionalis meridionalis</i>)	warm-tempered with signs of subtropical (+2-+4 / +22-+23; 500-600)

– mr_3) soils, which are distinguished by reddish shades of color, are the most clayed, ferruginous with a large number of nodules which concentration organ-iron-clay material; the bixed morpho- and micromorphological features indicate that such types of soils could only be formed in the heat-temperate with signs of subtropical or climatic conditions close to them;

- Lubny (red-brown saline – lb_{b_2} , dark-colored (brownish-cinnamon) fused – $lb_{b_2} + lb_{b_1}$), heavy loam soils, are less clayed, ferruginous, different by brown-gray a brownish tinge with the color of their profiles, the presence of moleholes, complex microaggregation; such features of the morpho- and microstructure of these soils are evidence of their formation in the meadow-steppe and steppe conditions of a moderately warm transition to a subtropical climate;

- Zavadvka (cinnamon and cinnamon saline – zv_{b_1} , reddish-brown saline – zv_{b_2}), heavy loam soils, which are a transitional variant to the temperate climate, although some features of the lower Pleistocene soil formation remain (ferrugination, presence of segregation clusters of organo-clay and clay materials, microortshteins) and probably formed in moderate variably-wet close to subtropical climatic conditions;

- Kaydaky (cinnamonish-brown – kd_{b_1} , chernozems ordinary – kd_{b_2}) and Pryluky (cinnamonish-gray saline – pl_{b_1} , chernozems saline – pl_{b_2}), brown steppe – pl_c), heavy and medium loam soils are characterized by grayish shades of their profiles coloring, presence moleholes, carbonates, complex microaggregates, pores; the listed signs indicate that these soils were formed in moderately warm, uniformly humid climatic conditions; they are the closest to the modern soils that are currently distributed in the territory of Ukraine;

- Vytachiv (cinnamonish-brown – vt_{b_2}) heavy loam soils formed under the influence of turf (the presence of moleholes, carbonate, complex microaggregates) and brownzem-liked (cinnamonish-brown coloration of the profile, spatial structure of clays) of the soil forming processes of a moderately warm subarid climate and have no analogues in the modern soil cover of our country;

- Dofinivka (chernozem saline – df_{b_2} , brown saline and brown desert-steppe – df_c), medium loam soils, with clear features of xeromorphism (low profile power, its carbonaceous nature, absence of signs of organo-mineral material redistribution), formed in moderately continental and more arid (dry) climatic conditions compared with modern ones.

The established types of Pleistocene soils, their

morphological and micromorphological features reflect changes in paleogeographic conditions from Kryzhanivka, Shyrokyo, Martonosha, Lubny and Zavadvka paleogeographical stages, soils formed in warm-temperate climatic conditions with signs of subtropical or close to them. The established types of soils of the Kaydaky, Pryluky, Vytachiv and Dofinivka stages are evidence of their formation in temperate climates.

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